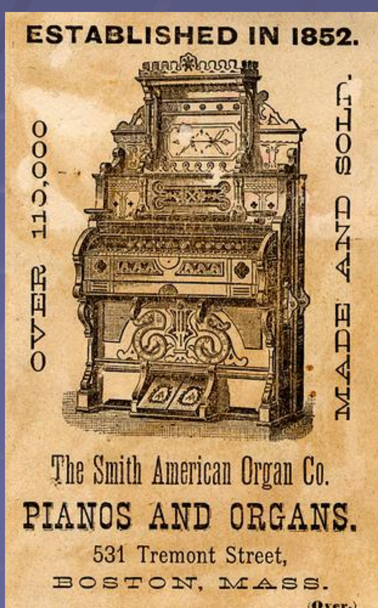
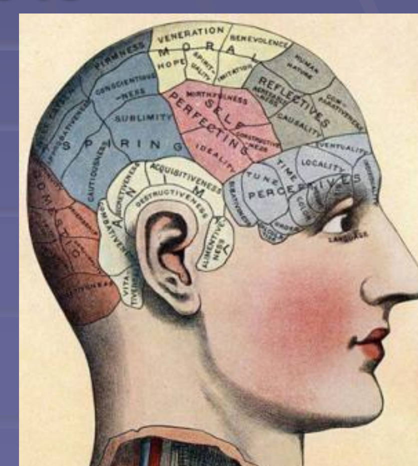
The Organist from fingertip to brain and back again



American Guild of Organists

July 2010



To create music

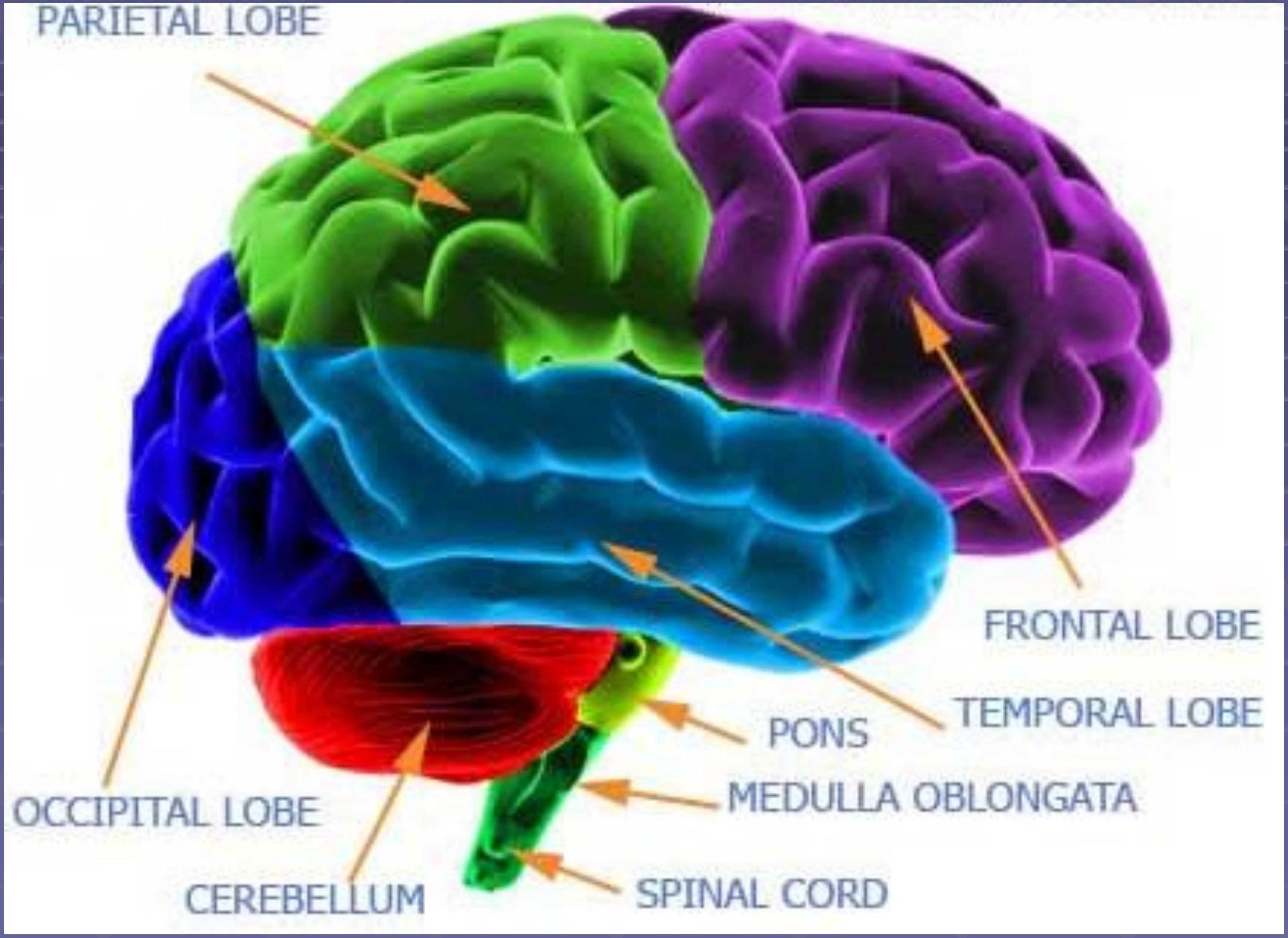
- Complex interplay between the sensory (visual, auditory, tactile, position sense), motor (output to peripheral muscles) and centers in the brain processing higher order, interpretive functions.
- These include language processing centers, executive function, “limbic” emotional, memory centers, and cerebellar and basal ganglion input to promote orderly output and neuromuscular control

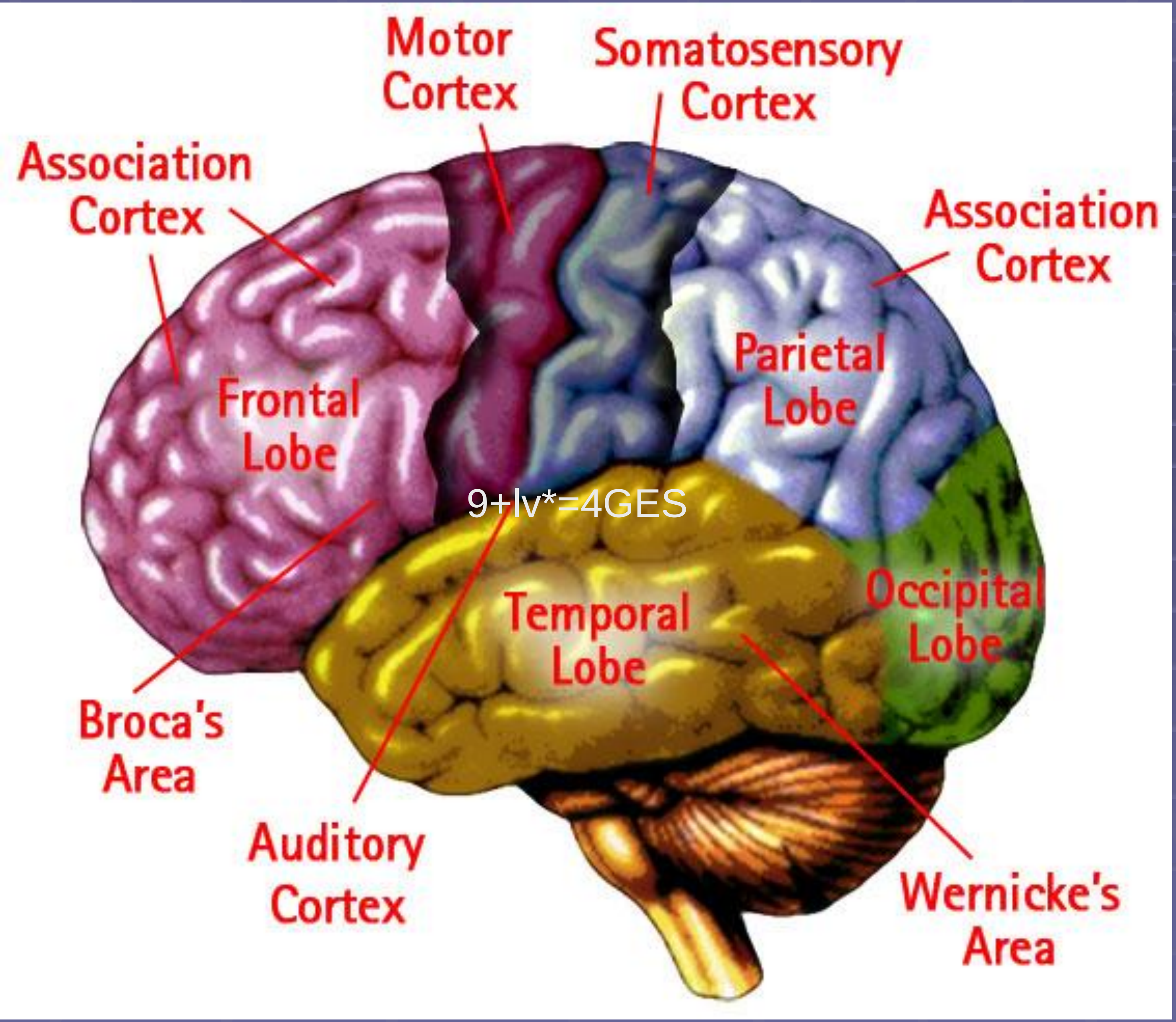
Movement

- Movement is a complex sequence of events that begin with input from the sense organs in the hand, eyes and ears that travel up the afferent sensory nerves to terminals in the spinal cord

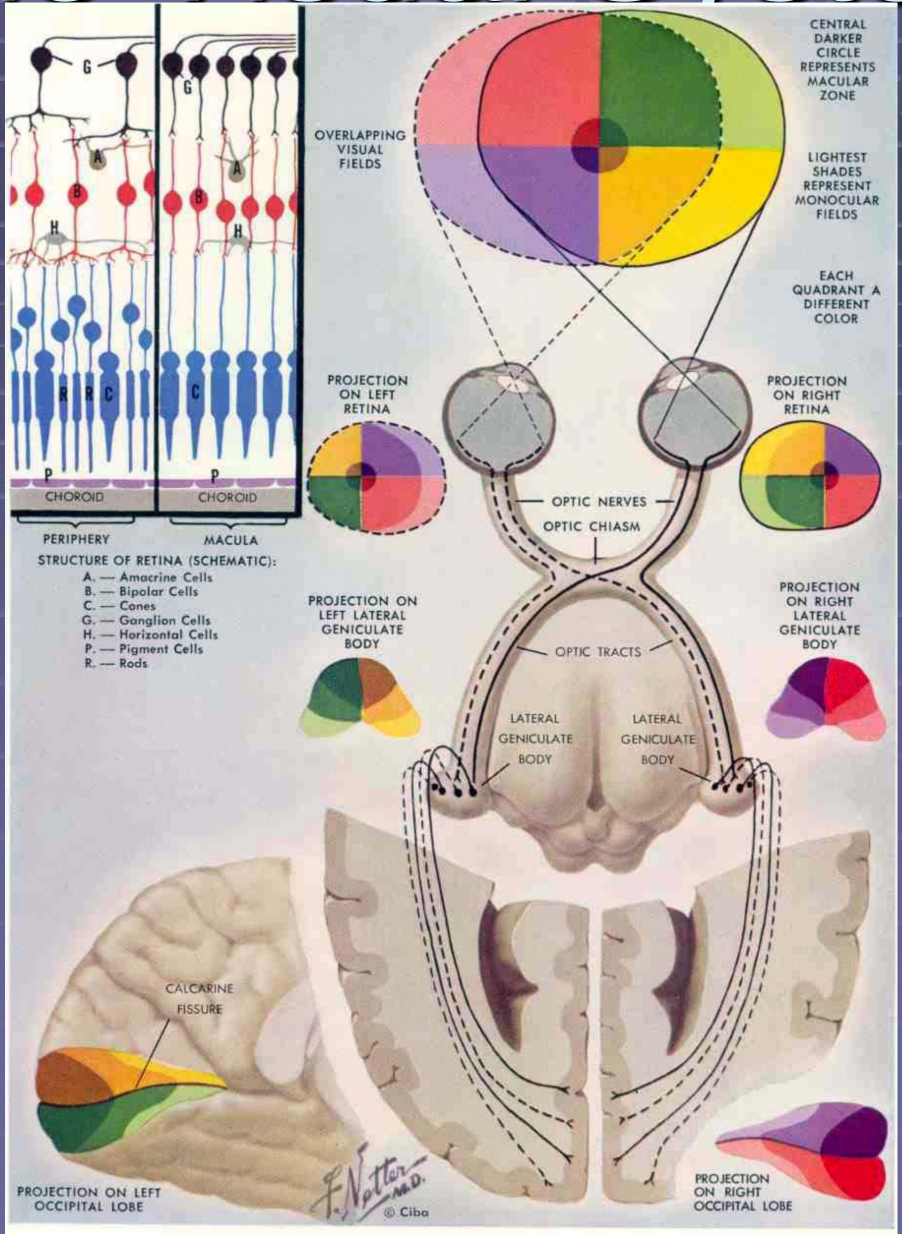
In the Brain

- From there the nerve impulse travels up the sensory fibers to the receptor areas in the brain for touch, hearing and sight.
- They then pass through a complex series of inter-neuron switching systems that eventually connect to the motor cortex in the brain.


PARIETAL LOBE
FRONTAL LOBE
TEMPORAL LOBE
PONS
MEDULLA OBLONGATA
OCCIPITAL LOBE
CEREBELLUM
SPINAL CORD


Motor Cortex
Somatosensory Cortex
Association Cortex
Association Cortex
Parietal Lobe
Frontal Lobe
9+lv*=4GES
Temporal Lobe
Occipital Lobe
Broca's Area
Auditory Cortex
Wernicke's Area

The Visual System



The Visual System

- Foveal regions of retina- sharp contrasts
- Retinal ganglion cells send axons to the cortex parallel pathways via optic nerve
- First stop lateral geniculate nucleus in the thalamus
- From there to visual cortex in the back of the brain

Visual system-2

- Temporal side of retina go ipsilateral brain. nasal side crosses over to the other side
- Left sided images goes to right side of the brain starting at the lat geniculate in different layers color, motion, form,contrast
- Orderly representation of the images, map,

Visual system

- In the visual cortex (area 17) representation still orderly
- Projections to higher order visual areas to decode the info
- Parietal lobe where in space?
- Temporal lobe what does it mean?
- Decoding musical notes

The Auditory System

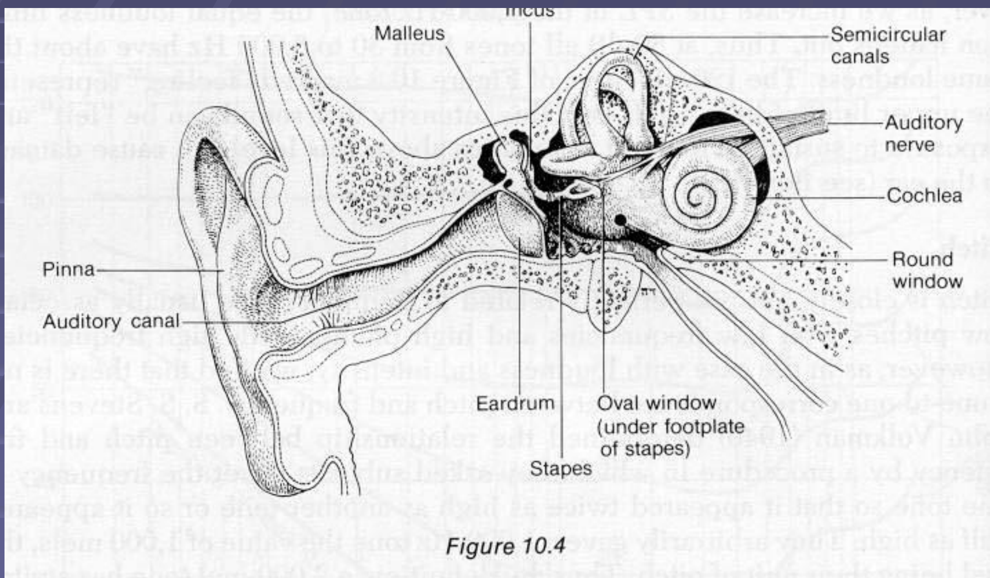
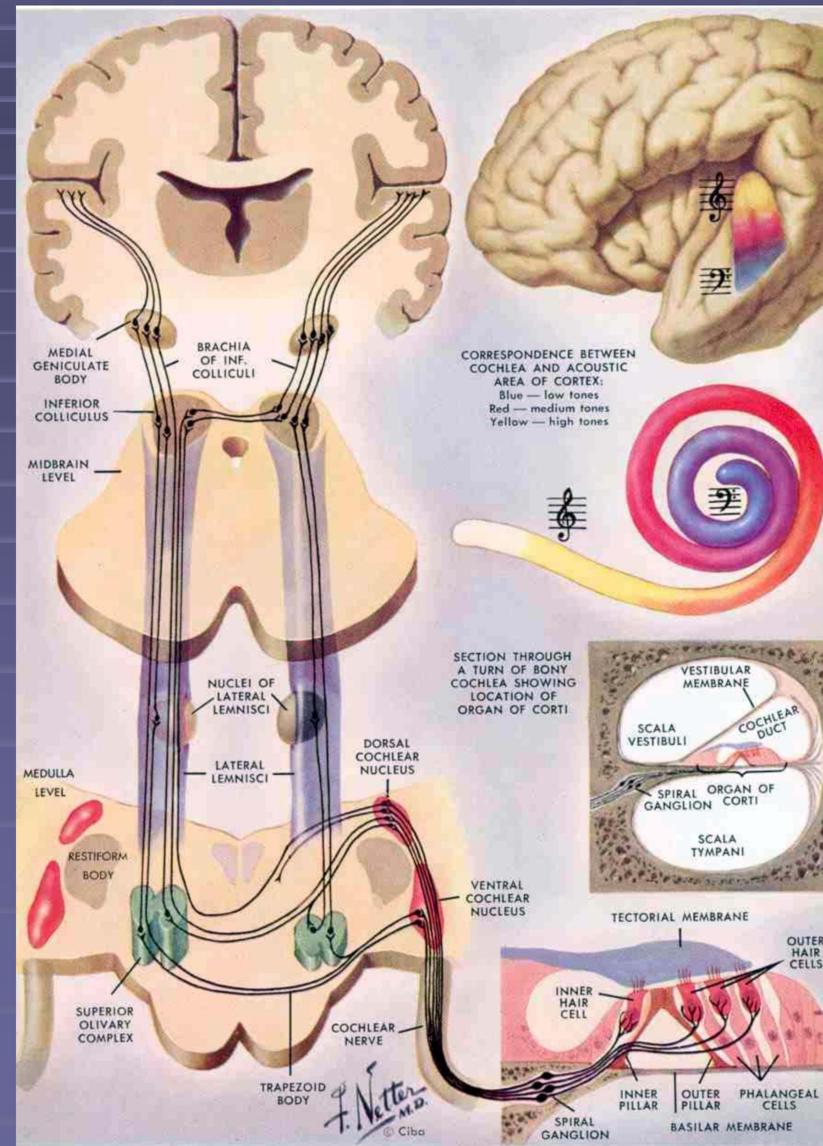


Figure 10.4



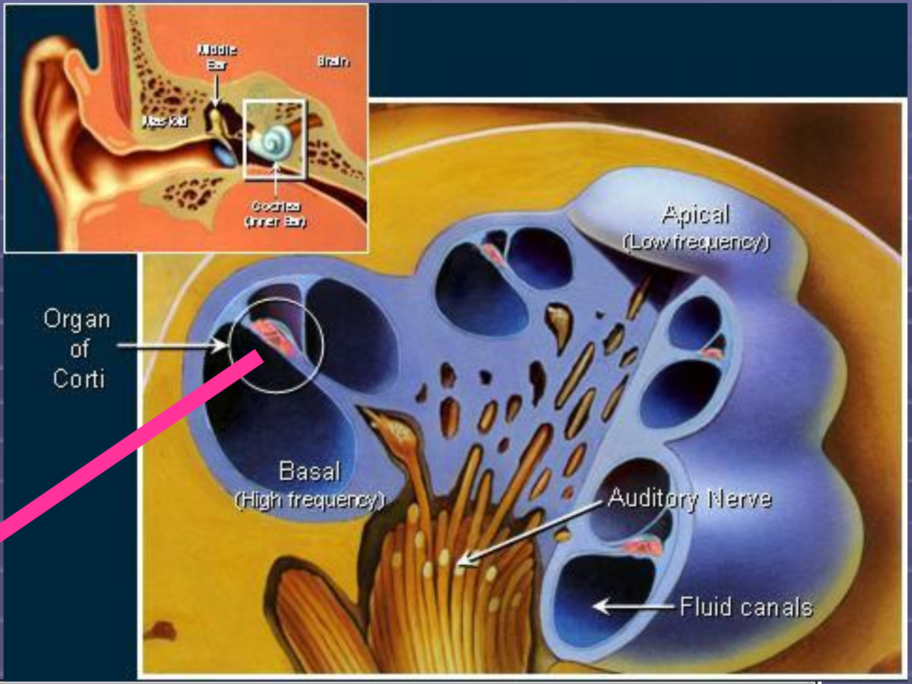
The Auditory system

- Pressure (sound) waves affect receptors that turn into electrical energy that brain interpret as sound
- Vibrates drum (tympanic membrane) to middle ear to inner ear to cochlea fluid medium
- Middle ear bones focus acoustic energy to fluid of cochlea amplifies sound

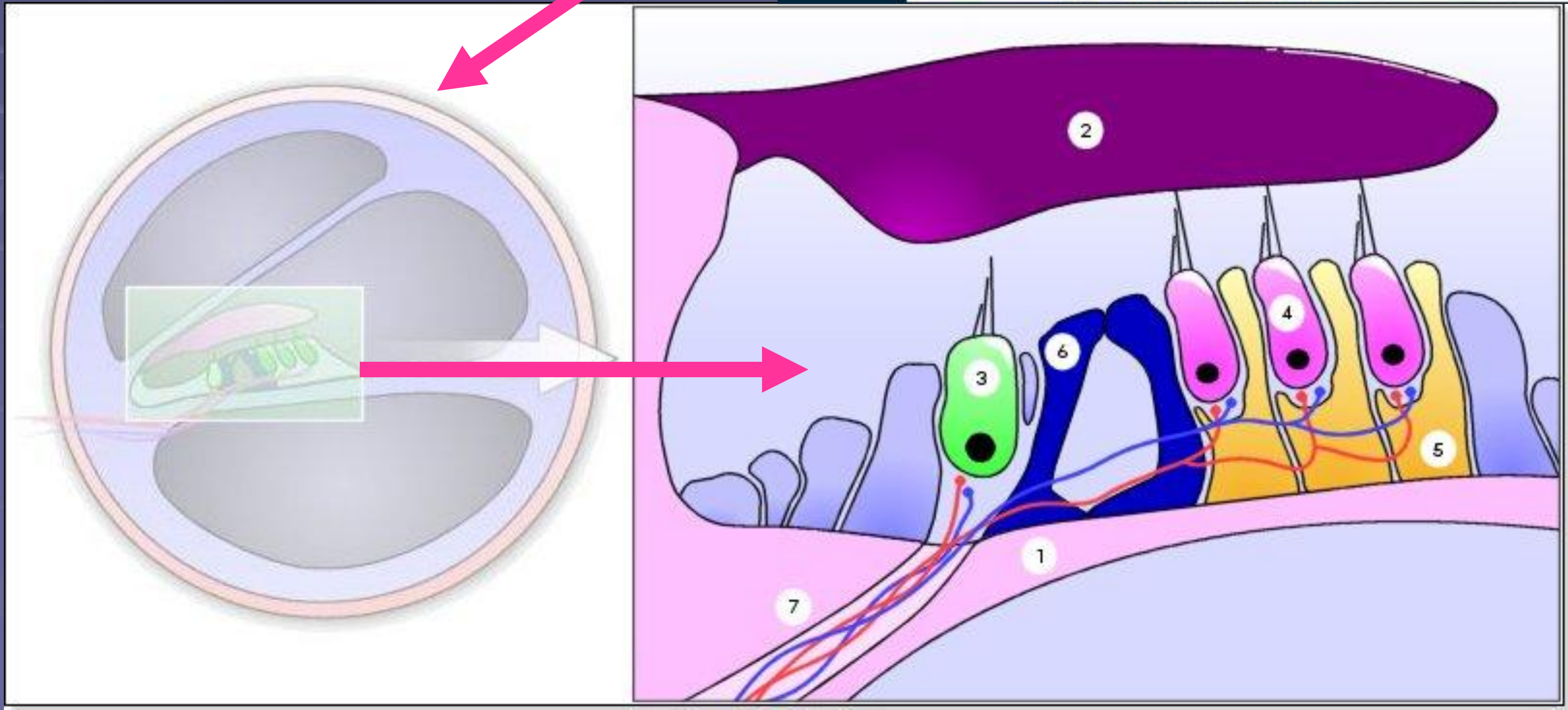
Auditory system

- Organ of corti = vibration membrane stimulates auditory receptor neurons (hair cells) differentiates different sound frequencies- traveling wave comes down
- Hair cell deflected send signal to otic nerve
- Point of maximal stimulation = varying pitches: high freq = base, low freq = cochlear apex= encoded by brain orderly maps

- Cochlea



Middle Ear
Brain
Cochlea (Inner Ear)
Apical
(Low frequency)
Organ of Corti
Basal
(High frequency)
Auditory Nerve
Fluid canals



2
3
4
5
6
1
7

Auditory system

- With aging, loss of hearing at higher frequencies = loss of flexibility of basilar membrane
- Extremely sensitive to loud sounds and can damage neurons
- Brain sends impulse to middle ear to dampen vibration to protect loudness and lower amplification process

Auditory system

- In the brain= complex, to process sound coming in from 360°, ears separate
- Brain needs to process where sounds are coming from, type of sounds, filter background noise
- Multiple parallel pathways to auditory nuclei in medulla from both sides multiple x-over to both sides, thalamus to cortex
- Medial geniculate nucleus to primary auditory cortex in temporal lobe to auditory higher order area in the temporal lobe

Auditory system

- Hearing is a personal subjective experience just like vision via cortical mapping
- Info is processed to make sense of it i.e. language and music
- Spontaneously active increase in rate of firing

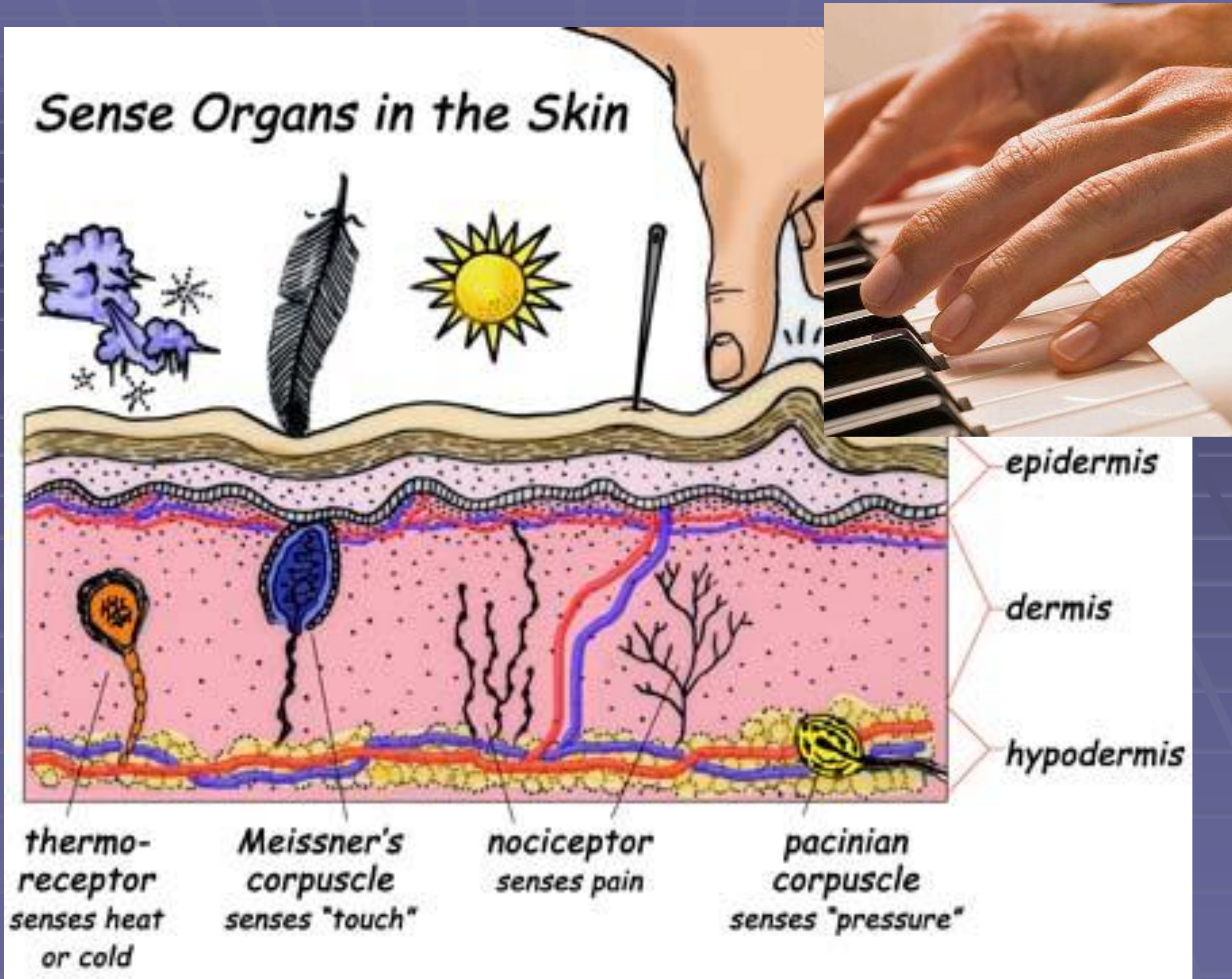
The Peripheral Sensory System

Somato sensory system

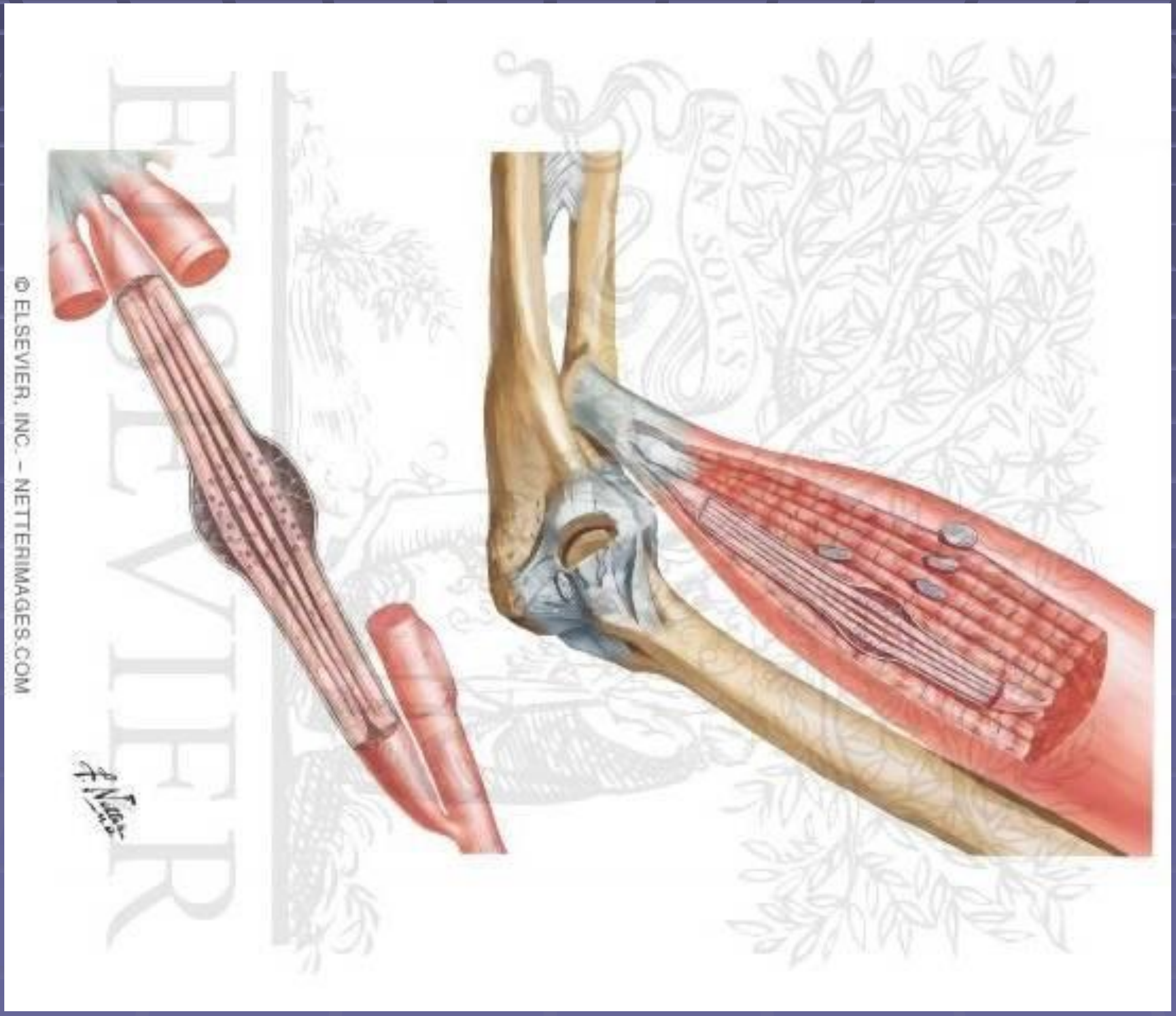
- Receptors located all over the body fire on/off
- Different receptors, pathways for different perceptions i.e. pain and touch
- i.e. pain, temp- free nerve ending
- fine touch discriminatory- size, shape and texture of objects meissner’s corpuscles
- Fingertips

Somato-sensory system

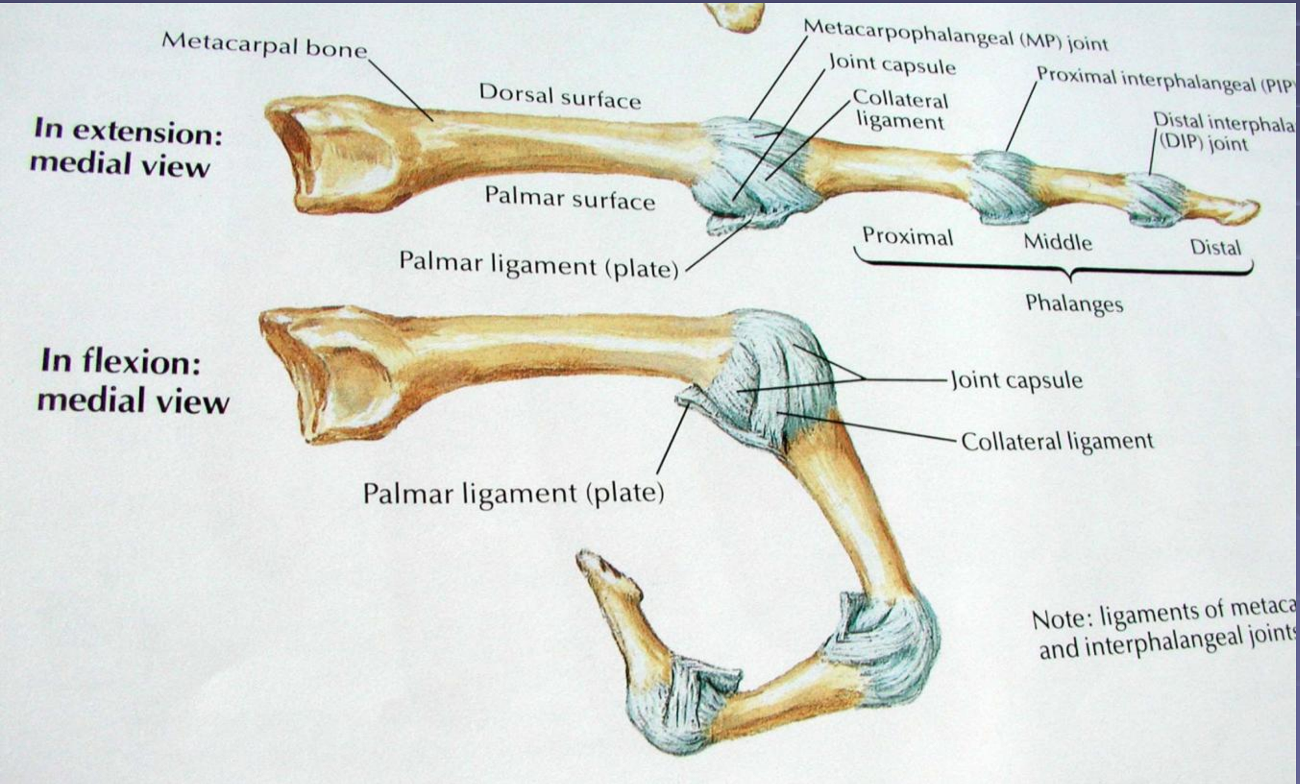
- Convey touch pain, temp and proprioception from our sense organs about our bodies
- Position sense static and dynamic info from joints
- Combined w visual = personal space and space at distance, feedback about our body state


Sense Organs in the Skin
epidermis
dermis
hypodermis
thermo-
receptor
senses heat
or cold
Meissner's
corpuscle
senses "touch"
nociceptor
senses pain
pacinian
corpuscle
senses "pressure"

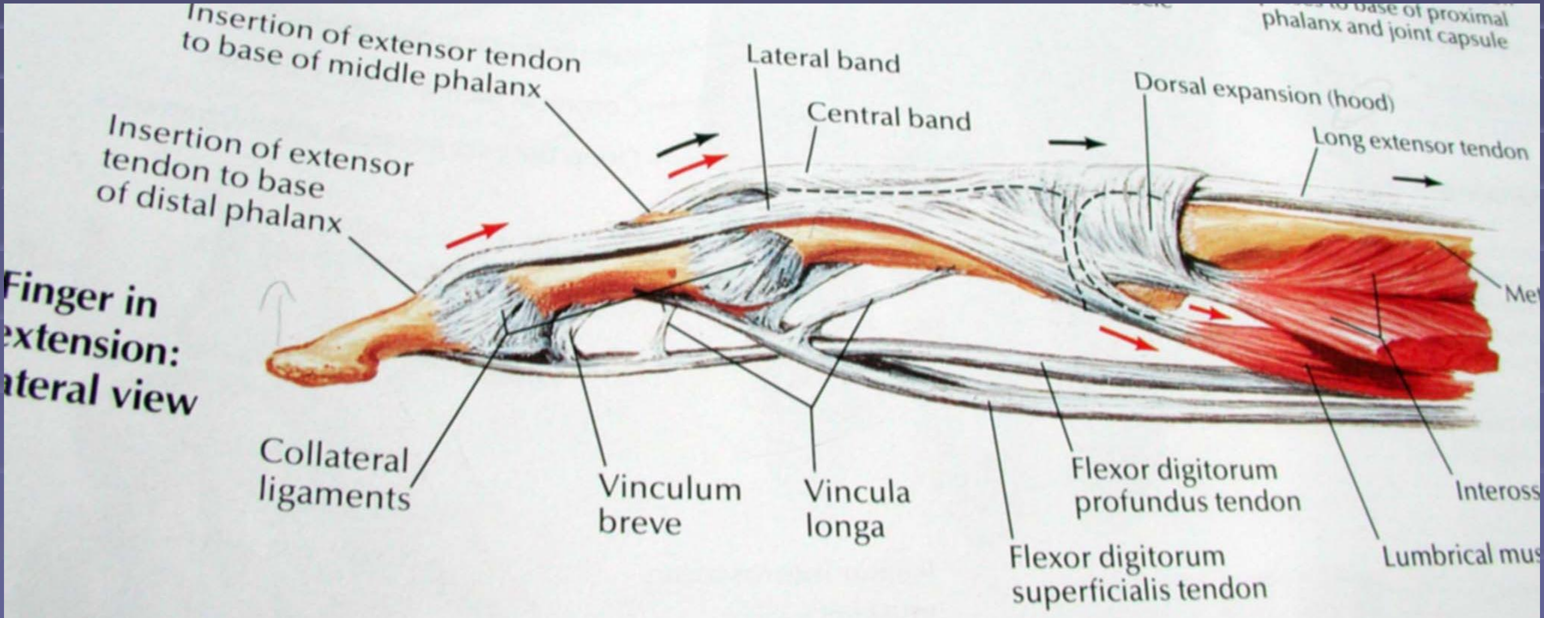
Joint stretch/position sense receptors



Bony anatomy of the finger



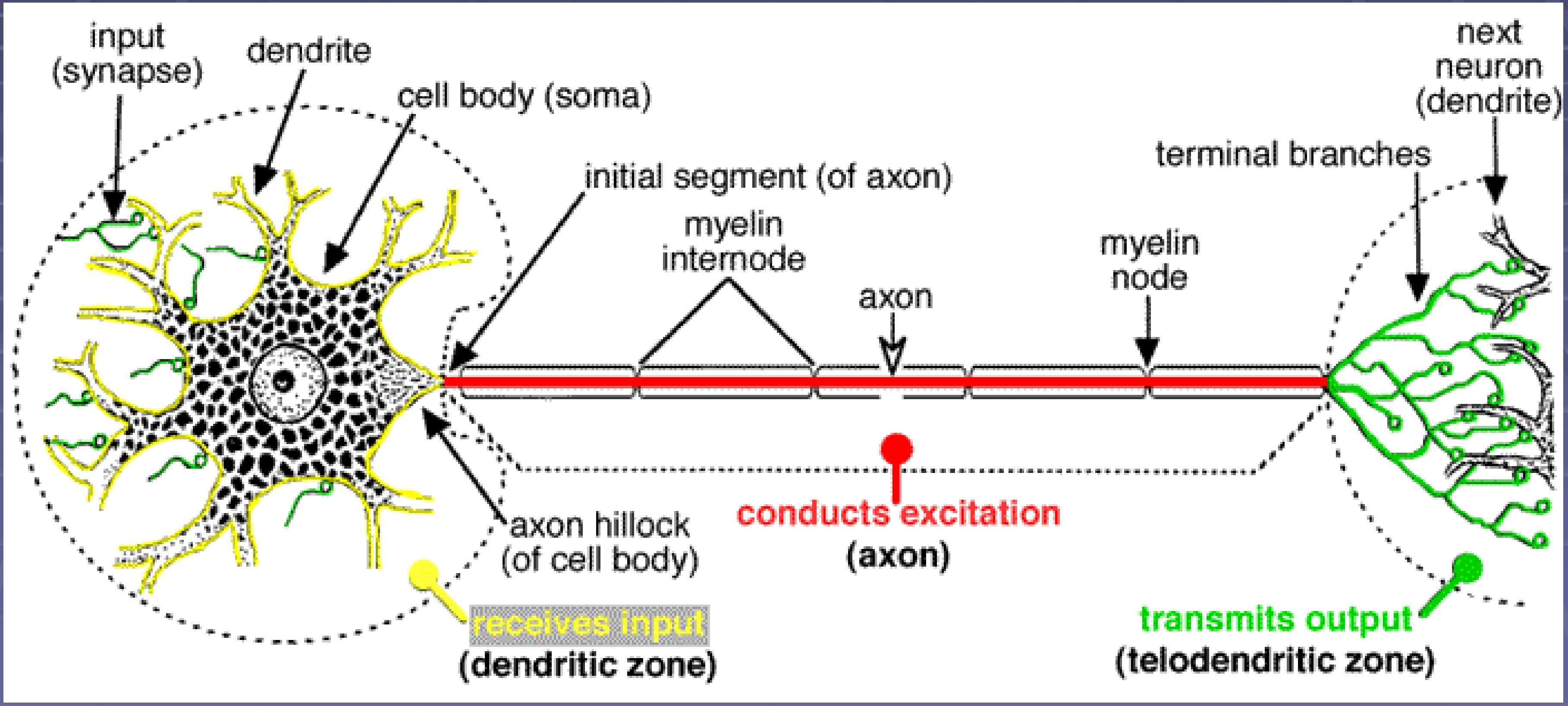
Flexor Tendon Anatomy



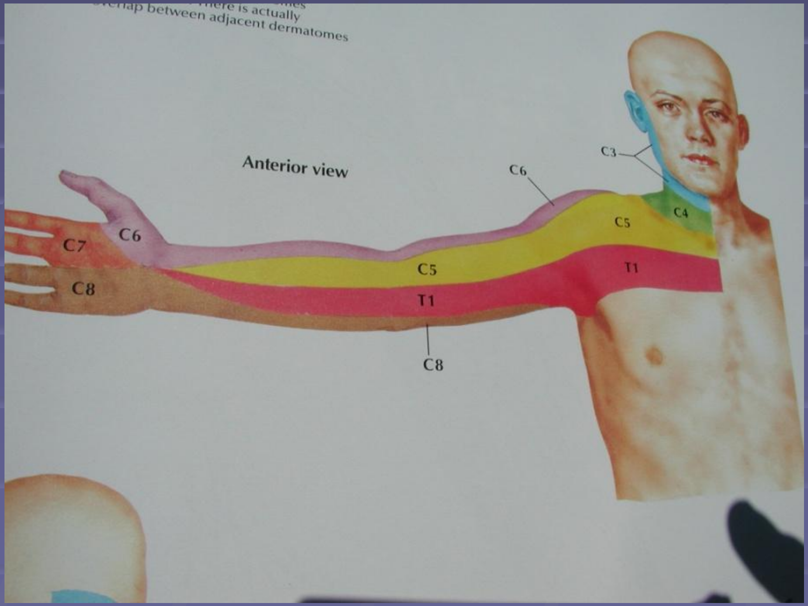
Sensory receptors

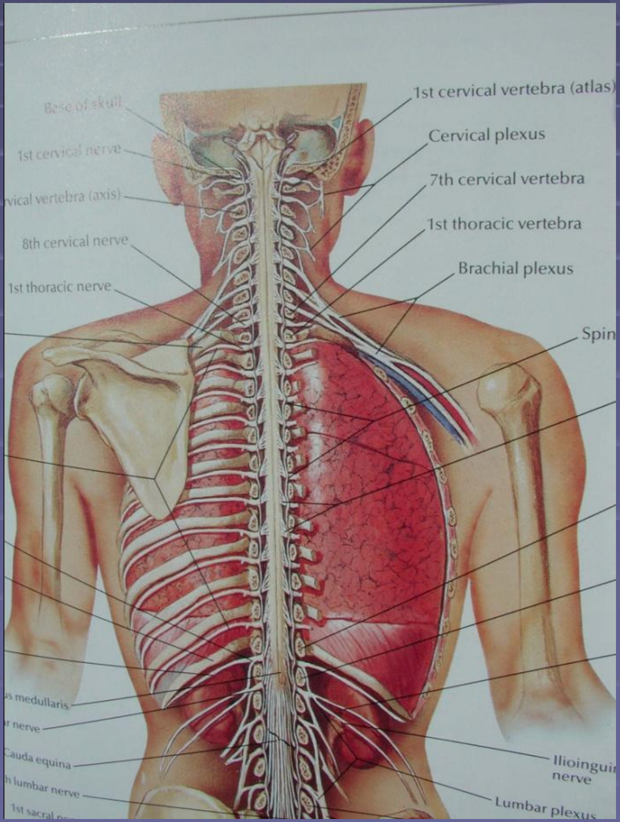
- Pacinian corpuscles- pressure touch (skin) and proprioception (joint) depending on location and varying parallel pathways
- Pain synapse in SC touch goes straight up
- Goes up to contralateral side of the brain
- Project to the thalamus to motor and primary somato sensory cortex (VPL) ventral posterior nucleus
- To higher order sensory area to interpret the meaning of the stimulus by mapping

A typical neuron

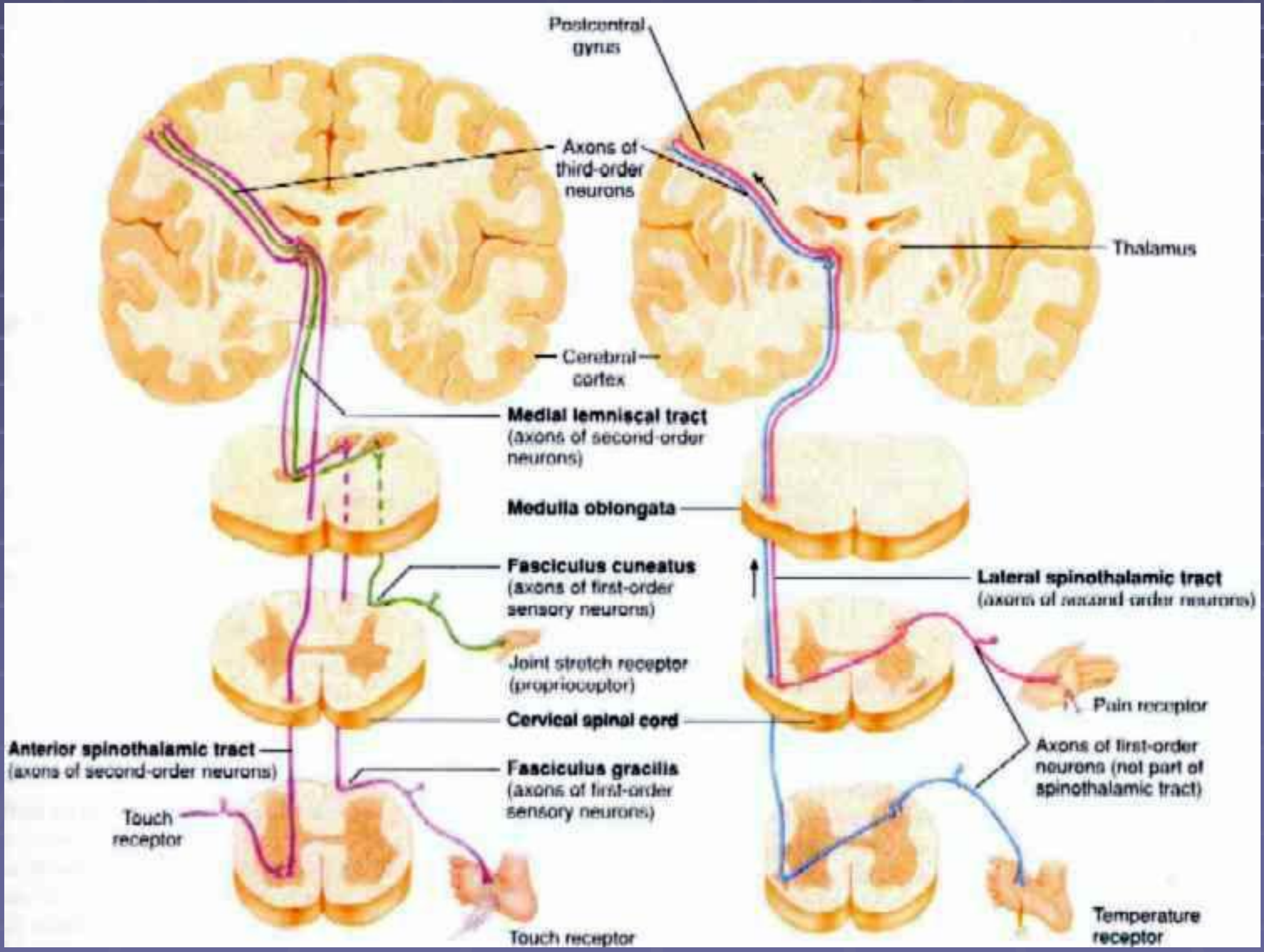


Periphery to Spinal Cord





The Pathway

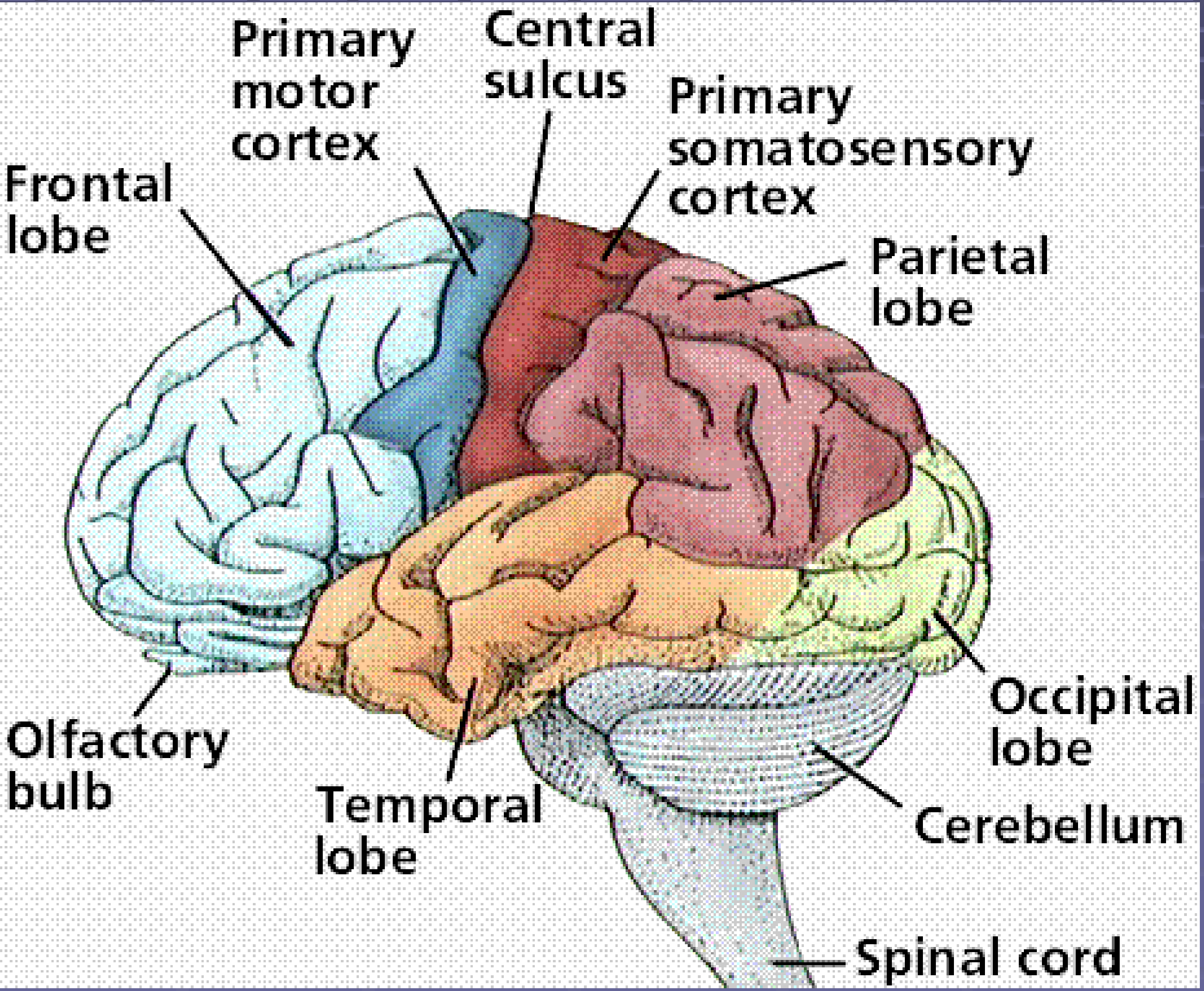


Postcentral gyrus
Axons of third-order neurons
Thalamus
Cerebral cortex
Medial lemniscal tract (axons of second-order neurons)
Medulla oblongata
Fasciculus cuneatus (axons of first-order sensory neurons)
Lateral spinothalamic tract (axons of second-order neurons)
Joint stretch receptor (proprioceptor)
Pain receptor
Cervical spinal cord
Anterior spinothalamic tract (axons of second-order neurons)
Fasciculus gracilis (axons of first-order sensory neurons)
Axons of first-order neurons (not part of spinothalamic tract)
Touch receptor
Touch receptor
Temperature receptor

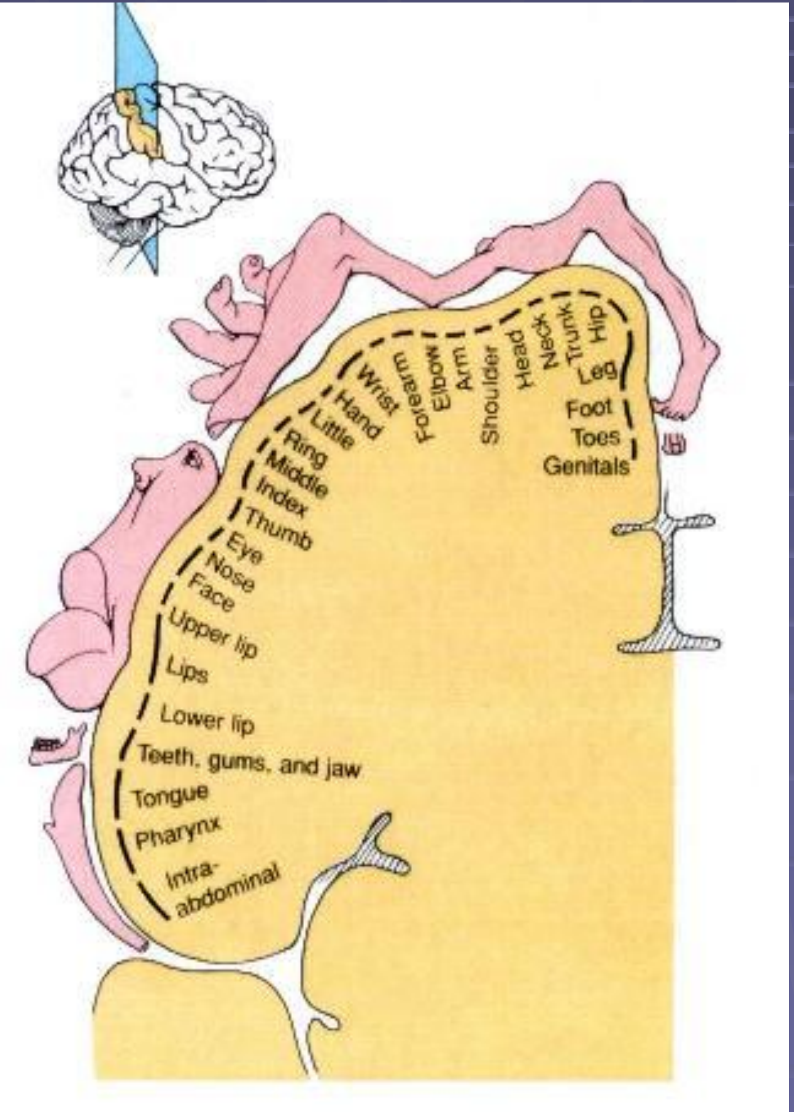
Somato sensory map

- Homunculus orderly projection of body surface “distorted” to justify areas of high acuity processing
- Pain doesn’t go up to the cortex. It just goes to thalamus for processing
- Cortical inhibition coming down to sc and gating a dampening of pain, perception of pain, threshold and placebo effect
- Emotional component of pain -lobotomy

Sensory cortex



Sensory cortical map



(a) Somatosensory cortex in right cerebral hemisphere

When things go wrong

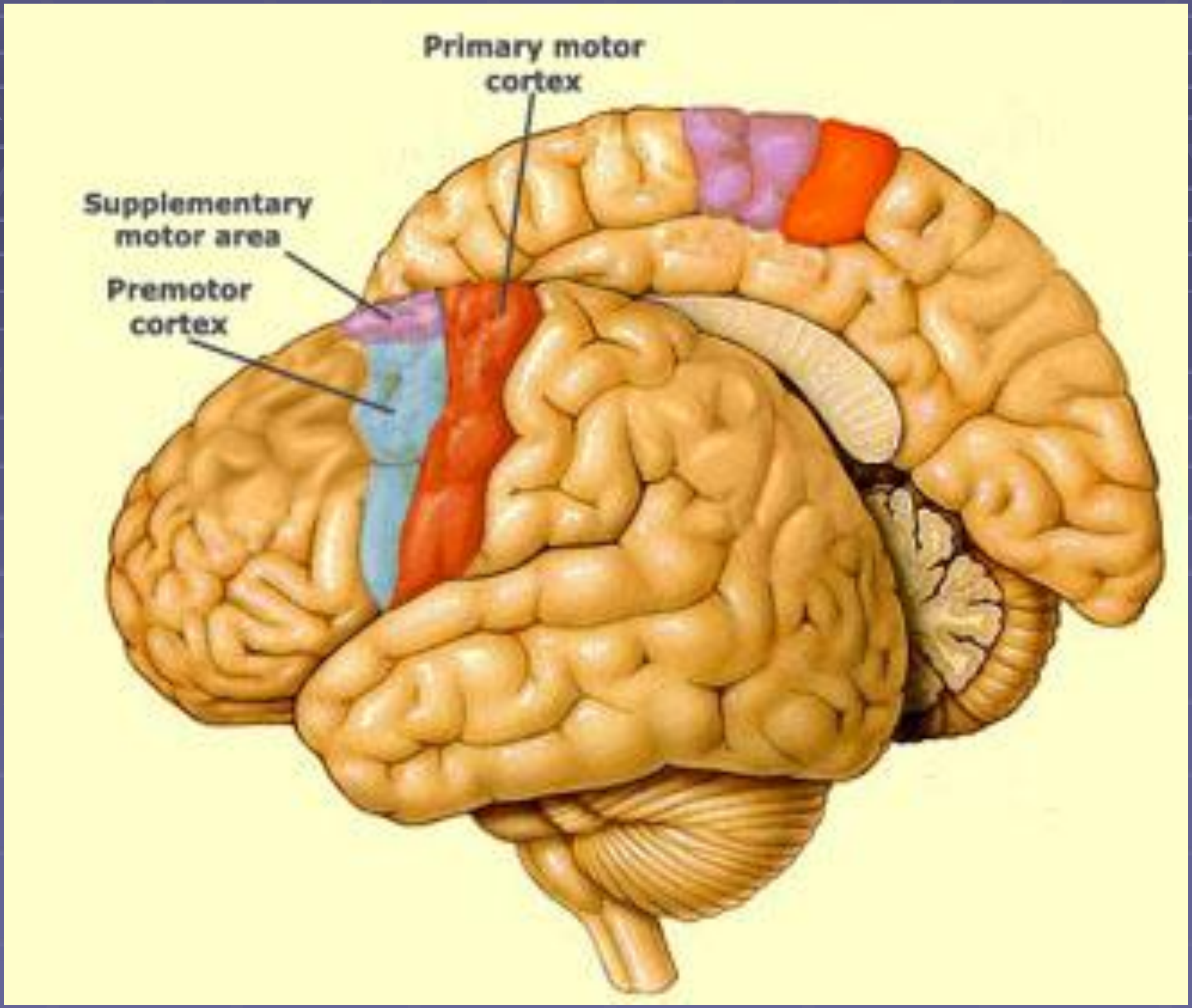
- Lesions in particular regions of the brain will affect a person's subjective experience
- Extra striate visual areas parietal ,temporal occipital lobes=agnosia (loss of knowledge) primary visual cortex intact, loss of recognition
- Motion agnosia- inability to experience motion- world of still frames

Types of agnosia

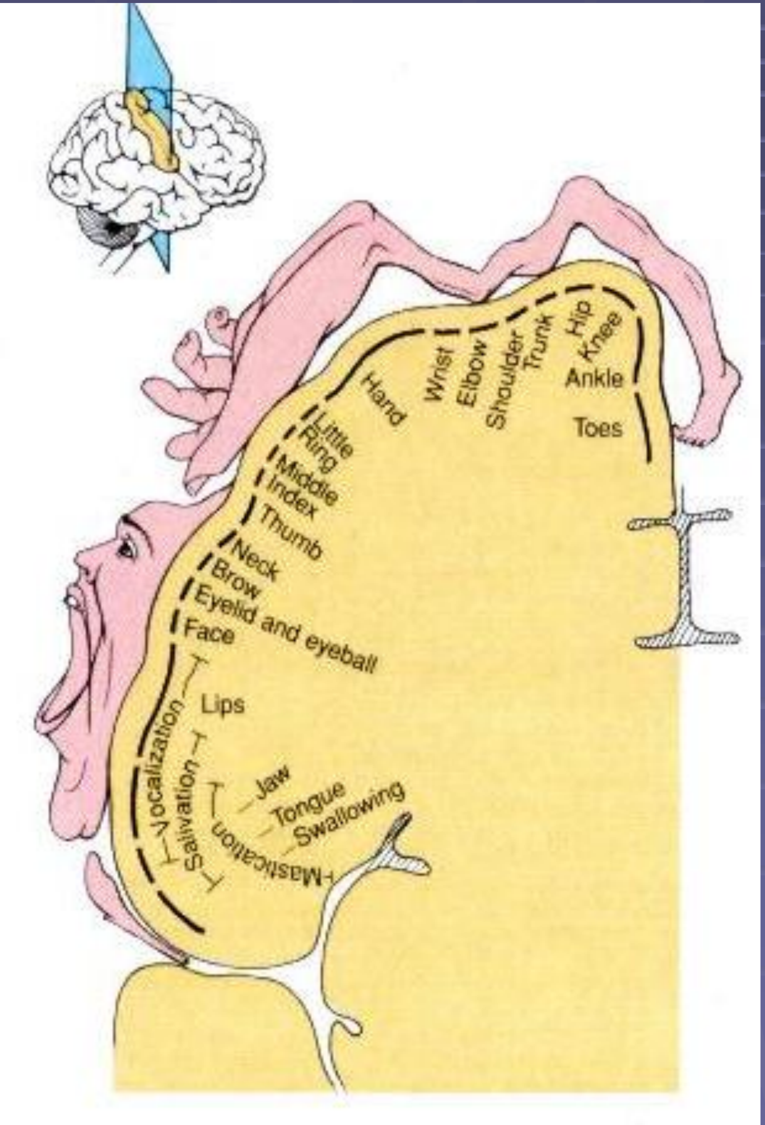
- Color agnosia- can see different wavelengths but cannot see ‘color’ –not color blindness -look at the world in black and white
- Prosopagnosia- inability to recognize faces even himself or man or woman or animals
- Contralateral neglect- right parietal lobe only, loss of awareness of the entire left side of the body and world even with adl’s like grooming
- Loss of spacial memory of half of the world

Direct cortico- spinal pathway

- Initiated in the cortex going down
- Pyramidal, extra-pyramidal, cerebellum
- Pyramidal- initiates movement cortical spinal pathway projects to contralateral spinal cord-anterior horn cells out to muscles in the lower medulla exit at appropriate level
- Planning of motor function in frontal lobe in front of the motor cortex


Primary motor cortex
Supplementary motor area
Premotor cortex

Motor cortical map



(b) Motor cortex in right cerebral hemisphere

Motor representation in keyboard players

- Musicians who started training early in life have greater inter-hemispheric connections between 2 halves of the brain (larger corpus callosum) better coordination between both sides of the brain
- Representation of the hand in the motor map is larger in musicians in both sides
- Larger volumes of grey matter in musicians in motor and sensory areas, pre-motor and superior parietal lobes and left cerebellum
- **Level of skill and practice time correlate**

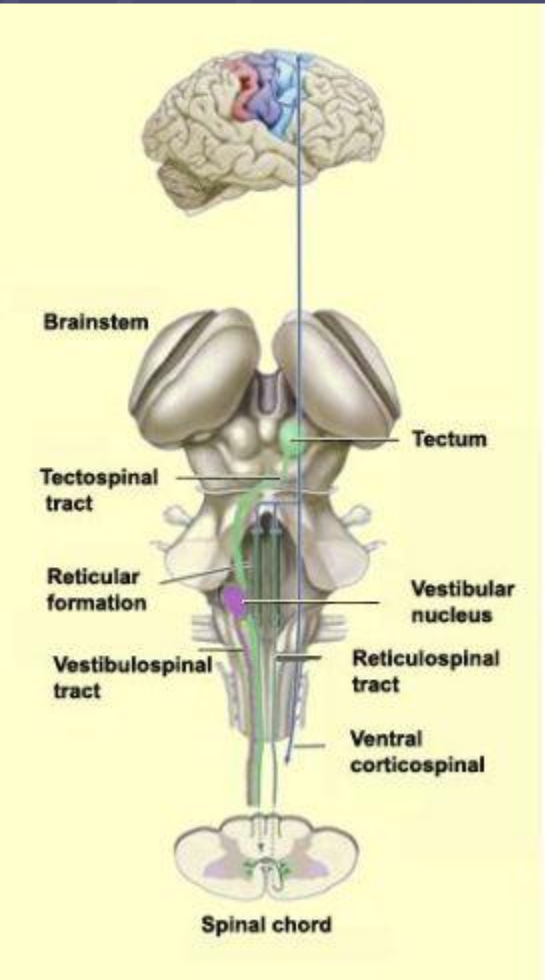
motor

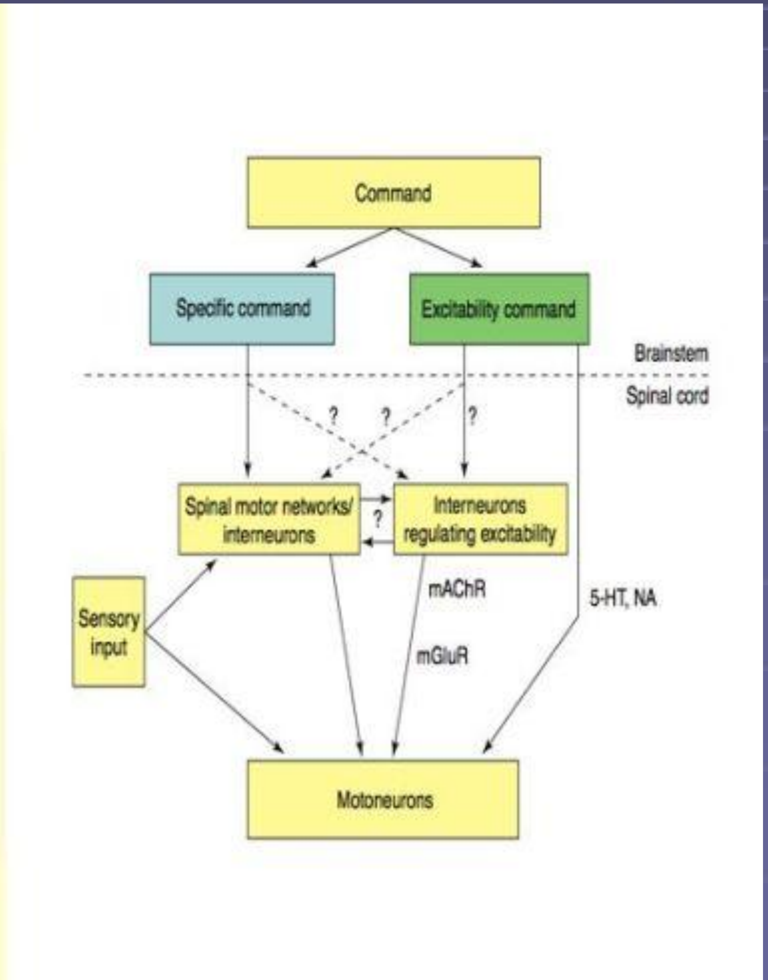
- Map of motor cortex orderly representation of contralateral aspect of the body proportional to sophistication of motor function
- Feedback from sensory cortex and decide what movement should be planned and executed

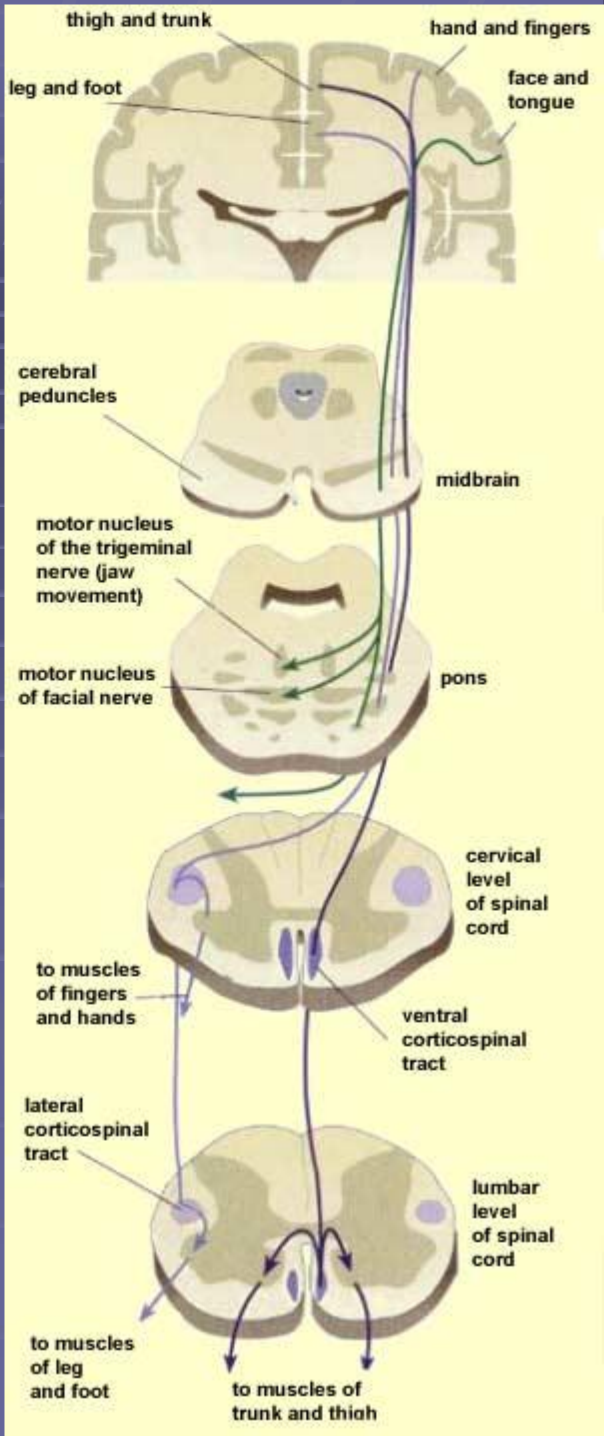
Premotor Cerebellar cortex

- The premotor cortex-Plays a critical role in the planning, preparation, execution, and control of bimanual sequential finger movements
- Cerebellar cortex-timing, rhythm, cognitive skill learning

Descending motor pathways

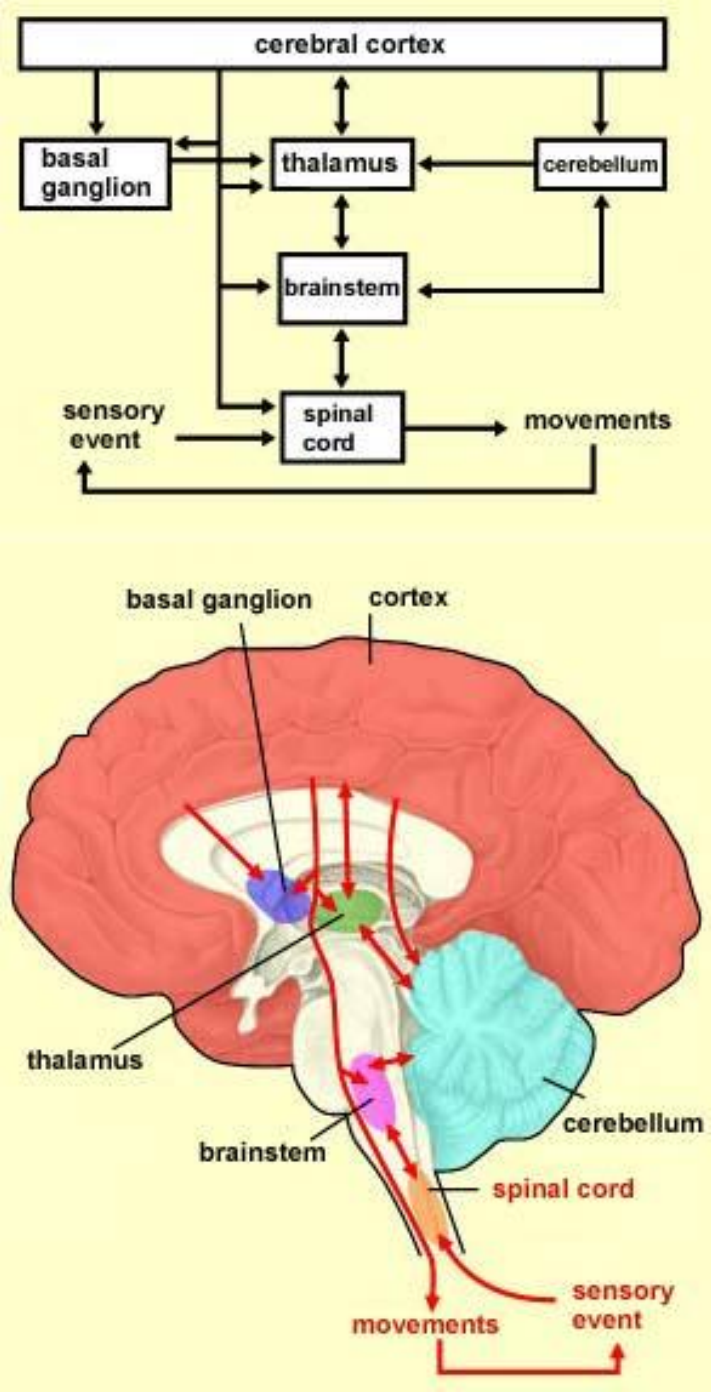






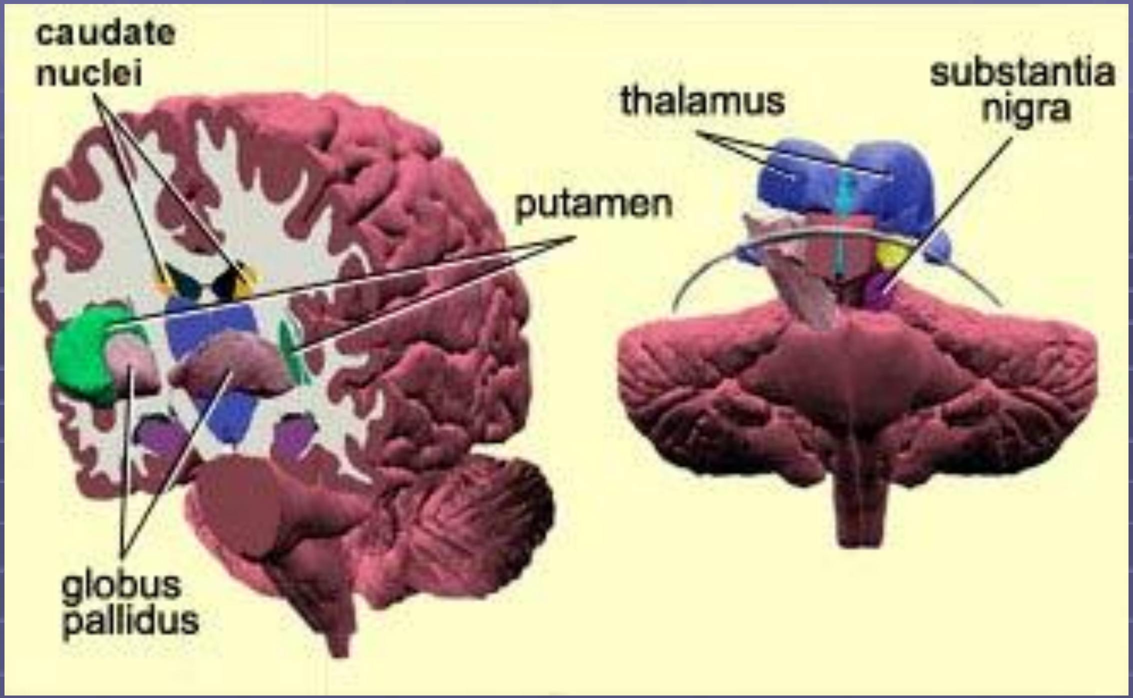
Indirect corticospinal pathways

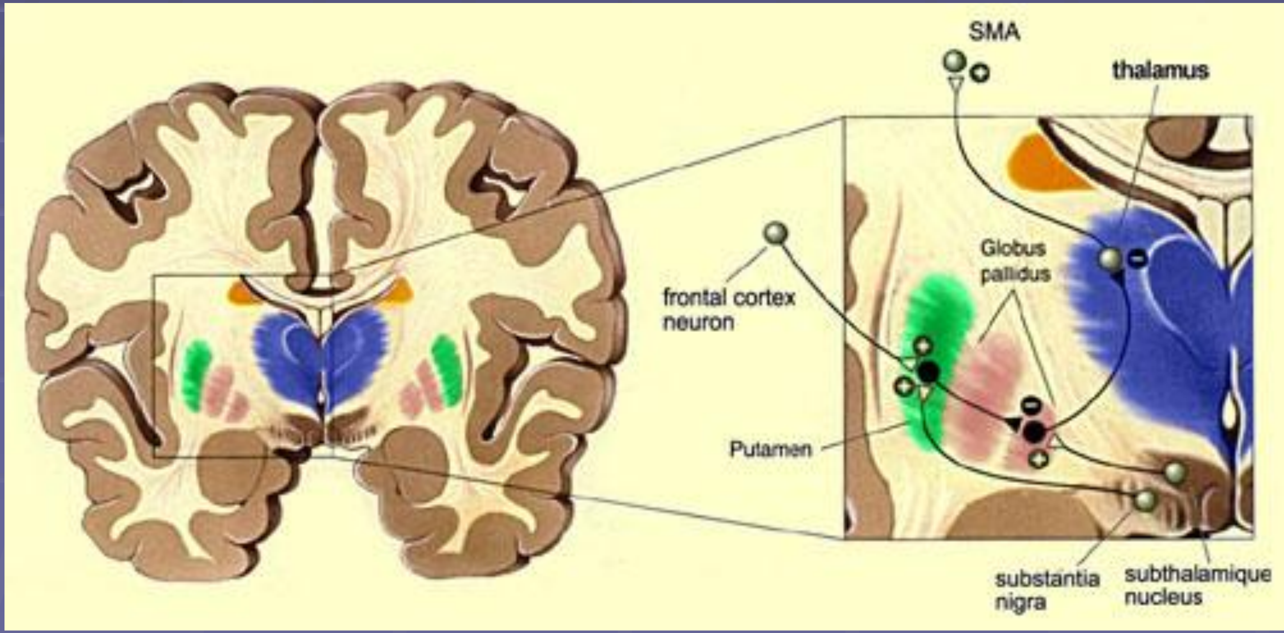
- Cortex to brain stem nucleus to anterior horn cell maintain antigravity muscles – resting tone. Course with direct


cerebral cortex
basal ganglion
thalamus
cerebellum
brainstem
sensory event
spinal cord
movements
basal ganglion
cortex
thalamus
cerebellum
brainstem
spinal cord
sensory event
movements

Extrapyramidal system

- Play a role in motor programs and motor learning and automatic movement
- Basal ganglia nucleii, subthalamic nucleus, substantia nigra, caudate nucleus, putamen, globus pallidus
- No projection into the spinal cord- feedback circuits into the cs-pathways via motor nucleii in the thalamus back to motor cortex

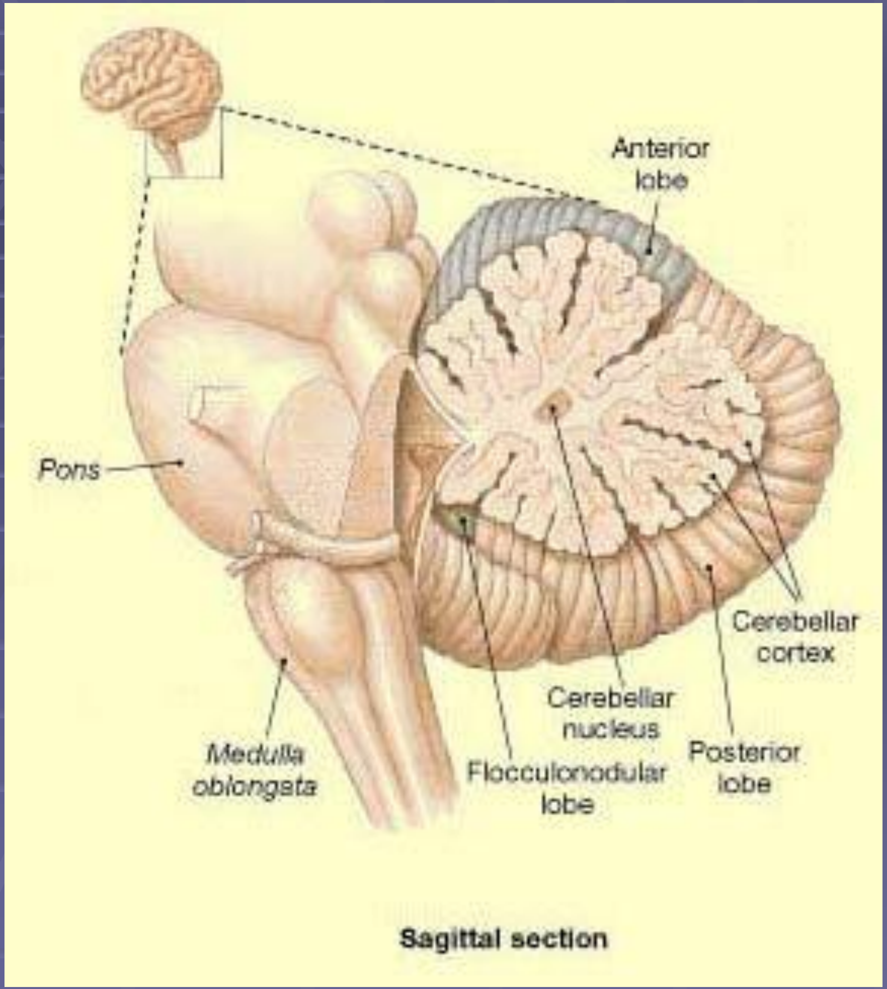

caudate
nuclei
thalamus
substantia
nigra
putamen
globus
pallidus


SMA
thalamus
Globus
pallidus
frontal cortex
neuron
Putamen
substantia
nigra
subthalamique
nucleus

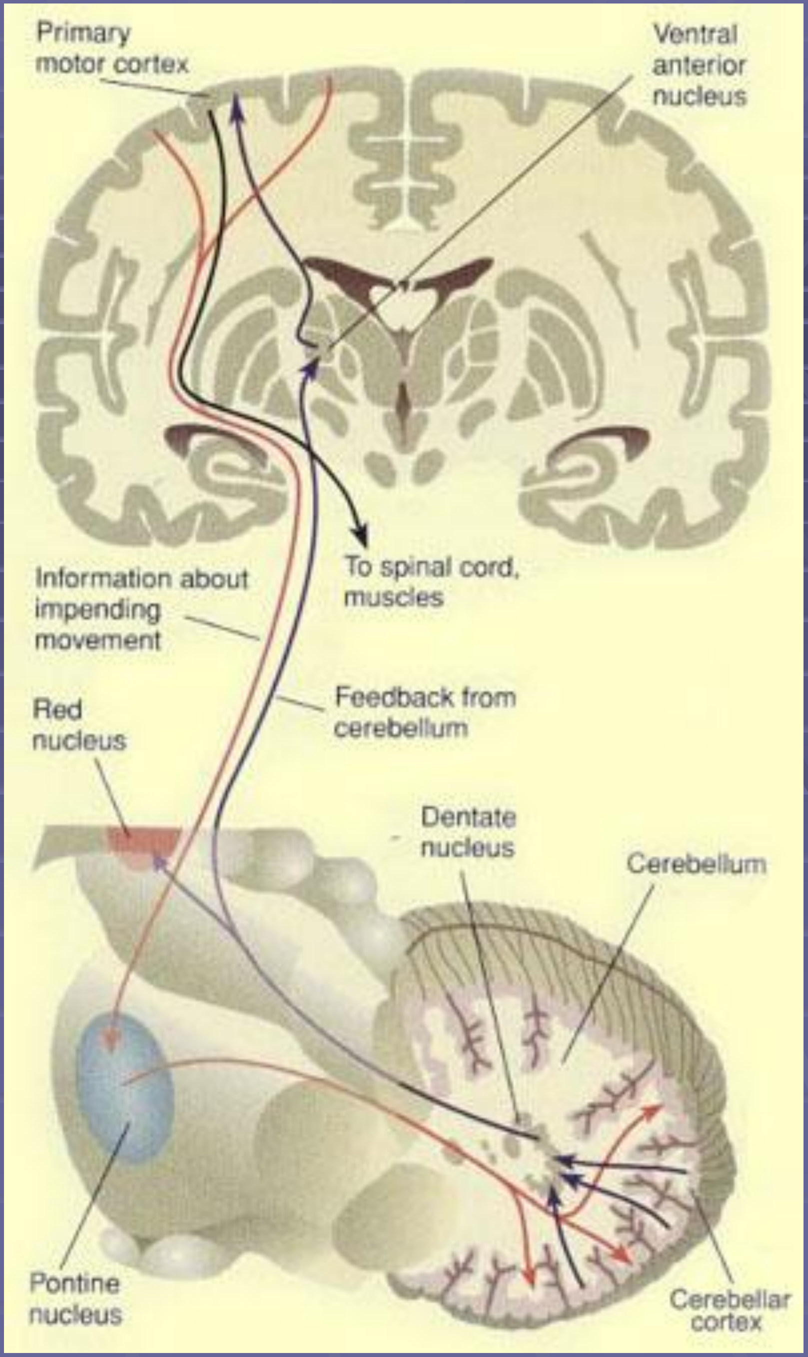
- Axon collaterals from corticospinal axons to basal ganglia and cerebellum so other areas of the brain know what movement is going to happen

Cerebellum

- Maintenance of equilibrium and posture
- Timing of learned skilled motor movement force and speed
- Correction of errors during ongoing movement
- Multiple motor and sensory maps too



Sagittal section



Inputs to cerebellum

- Motor cortex to pons to cerebellum via collaterals of cs tract
- Indirect cs and extrapyramidal
- Sensory input i.e proprioceptive, visual systems

Outputs from cerebellum

- None to spinal cord
- Feedback to direct and indirect CS pathways via the thalamus to modify movement
- Learn new movement set up neural circuits in the cerebellum with practice firing off cerebellar cells in a set sequence to set up automatic movements

FINE FUNCTIONS

- Consistency of coordinated motor movement after learning sequence improving with practice
- Reinforce motor circuits . Perkinjie cell firing sequence
- Has memory component of learned movement
- Translate sheet music, initially uncoordinated, with practice learn to touch correct keys then adjust tempo dynamics expression, articulation ALL CEREBELLUM

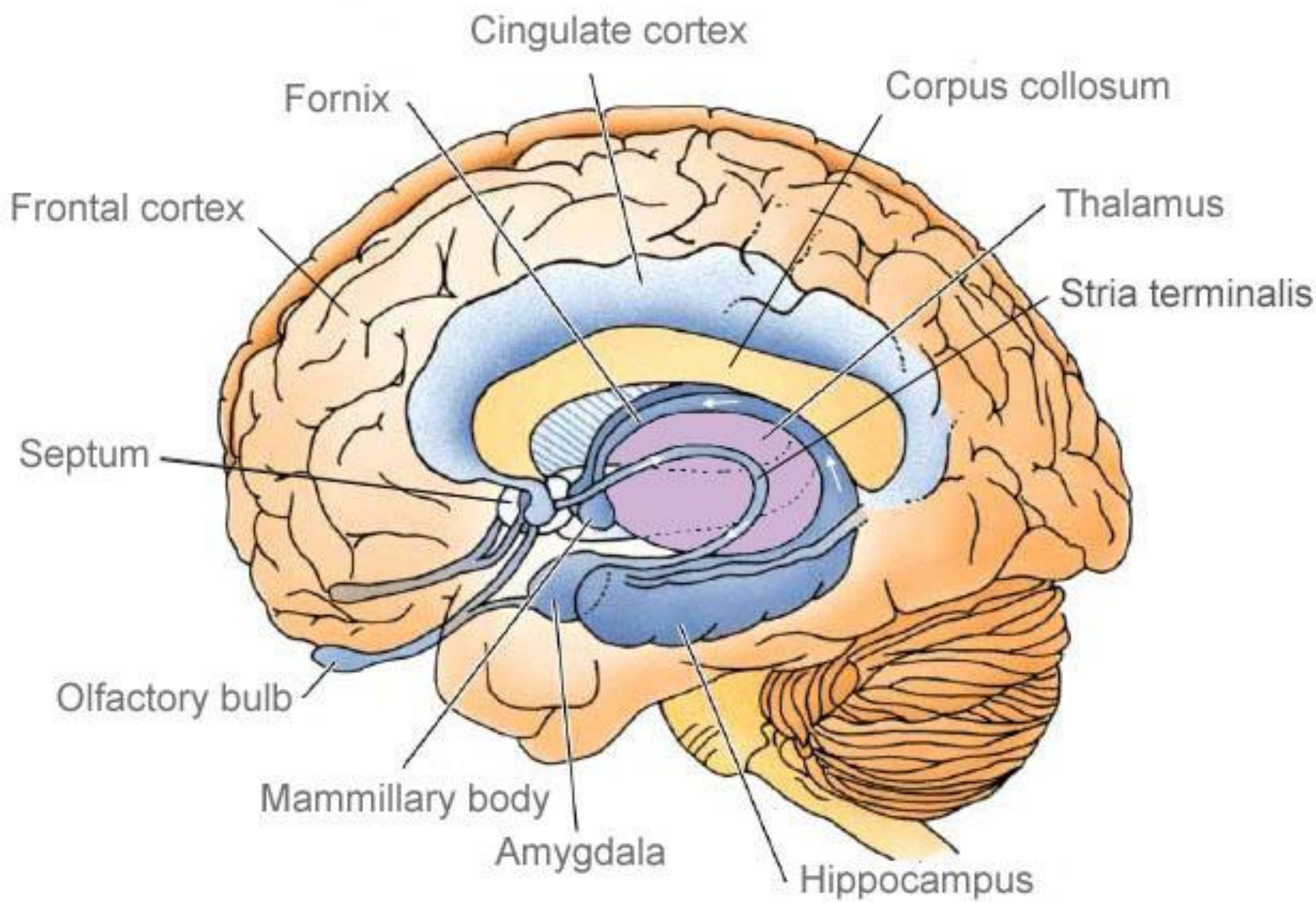
Dysfunction

- Dysmetria –finger to nose test timing force direction
- Dysrhythmia- loss of rhythm
- Dysdiadochokinesia- break down movement into component parts loss of smoothness
- Ataxia
- Intention tremor- near end of fine motor movement
- Language regulation, articulation, tone, speed,tempo

The Limbic System

- Helps us engage with the world and integrates many brain systems and attaches emotion to information
- Experience pleasure, emotional texture, memory, personality traits,learning, executive function, decision making
- Complex interconnected nuclei

Limbic System



Basal ganglia removed

Parts of the limbic system

- Hippocampus
- Mammilary body
- Anterior nuclei of the thalamus
- Cingulate gyrus, amygdala

- Complex feed back loops continuous mood regulation, comparison to the past, emotional coloring

Parts of the limbic system

- Medial surface of the hemisphere
- Hippocampus- learning and memory entorhinal cortex
- Amygdala- processing of emotions, emotional memory, fear
- Ventral tegmental area- drug addition nucleus accumbens septae
- Hypothalamus- embarrasment blushing

Learning to play

- Complex interplay between seeing the music notation, hearing what you play and the tactile (pressure) sensation being fed up to the various sensory processing centers in the cerebral cortex
- As learning progresses, cortical representation in the brain changes
- Receptive field become more “focused” to a specific activity and the overall sensory field enlarges

Neuro-plasticity

- The motor fields involving position sense, movement coordination and control of the strength of muscle group contractions increase correspondingly
- As skills are mastered, and tasks can be performed automatically, the areas of representation shrink and there may even be a loss in differentiation in cortical representation with overlapping fields i.e. across digits

To create plasticity:
Three training conditions

- “Learning” must occur with accommodation of new brain stimuli
- Progressive in level of discrimination and resolution of inputs
- Repetition and effort…..paced learning… the timing of input stimuli

- Inputs that arrive at fixed separated moments will create separate differentiated representations
- Inputs that arrive simultaneously will de-differentiate, integrate and “summarize” their representations

Learning and memory

- Limbic system modified by life experiences
- Malleable to change learning leads to memory
- Explicit declarative memory words and events
- Implicit memory non verbal and motor skills
- Working immediate memory < 30 seconds

- Short term memory first stage in learning
- Long term memory- lifetime can change with experience
- Prefrontal cortex, hippocampus extra pyr, amgdala higher order centers
- Emotional processing in memory

- Prefrontal cortex- working memory
- Hippocampus- short term learning and memory and some long term processing
- Left hippocampus – language memory i.e. words, auto biography creates a story of self, subjective

- Right hippocampus- spatial memory

Extra pyramidal system

- Motor automatic programs
- Amygdala- emotional memory
- Association neocortex- long term memory wide areas of rewiring. Last to go in Alzheimers

Synaptic plasticity

- Synapses get modified with learning and memory
- Change in responsiveness of post synaptic receptors change in membrane potential
- Increased release of neurotransmitter
- Change in dendritic spine shape changing efficiency of neural transport can change dynamically with learning

- Generate new synapses throughout life at the axon terminals in the inter-neurons or long axon systems
- After injury repair axonal sprouting to replace damaged axons
- Experiences- axonal growth cone and sprouts to create new synapses in hippocampus

humans

- Changes in synapses number,
- Sc cortex in musicians greater representation of fingers in the brain
- In people blind from birth have auditory centers also in visual cortex increased acuity

Emotion and executive function

- Neocortex, hippocampus, cerebellum
- Plasticity allows us to adapt with experience
- Emotion guides us through life’s choices and critical for rational behavior
- Prefrontal and limbic association cortex processing emotional info
- Apply morals to behavior

- Moral behavior was thought to be rational not emotional. Today emotional role dominates. Hooked up to reward systems
- Learned like language. Rules of social interaction absorbed as a baby
- Dorso-lateral frontal –executive function and decision making plugged into prefrontal emotional areas (orbital frontal cortex).
- Moral judgments will light up prefrontal limbic areas

Music vs sound processing

- Fundamental vs overtone. Fundamental is lowest sound in a tone and later blended frequencies that blend with the fundamental tone
- Relationship between tones, similar to language acquisition
- Similarities= rhythm, tempo and anticipation of ending (back to key note) like language intonation in each musical tradition
- Meaning mapped to sound relationships

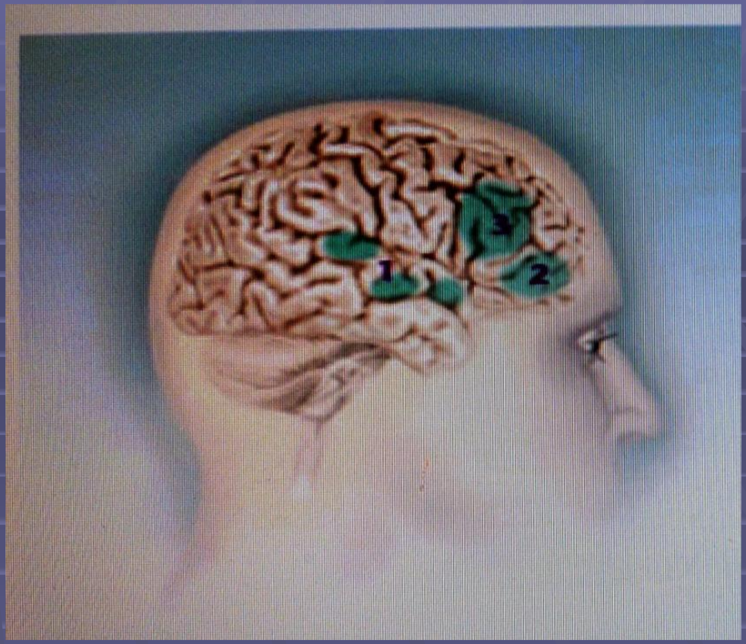
- Auditory and written representation which has meaning to trained eyes
- Music can be generated internally like words i.e. composers or recurrent tunes
- Music traditions acculturated very young
- Hemispheric dominance R&L equally good at processing tones
- Non musicians- right side melody and harmony, left side rhythm

Processing

- Primary auditory cortex- sharpening fundamental frequency
- Higher order areas in temporal lobe make meaning of the tones
- Emotional experience positive limbic endogenous reward system endorphin and dopamine release
- Hippocampus- ability to remember long sequences of music
- Cingulate gyrus

Stages in musical performance

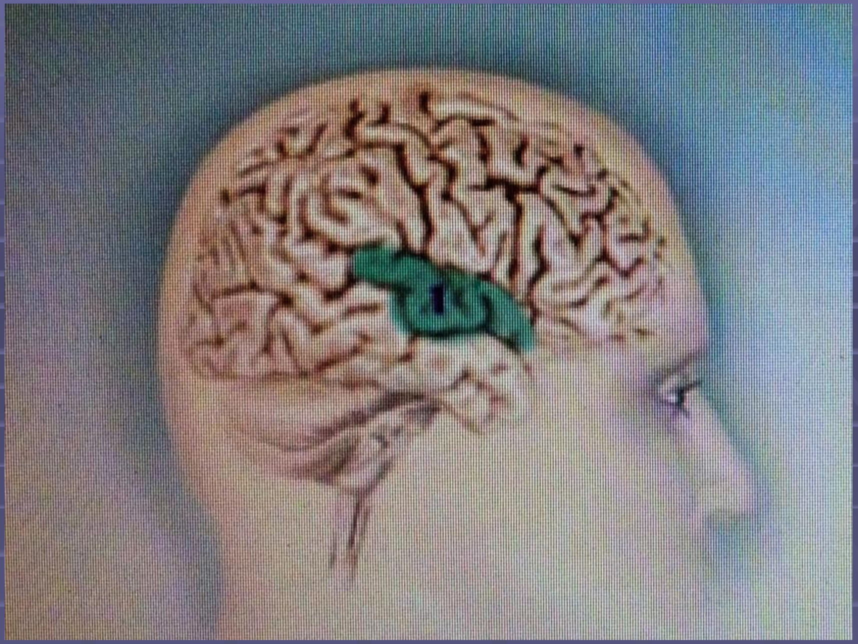
- During imagery and planning bilateral premotor, superior parietal lobes active

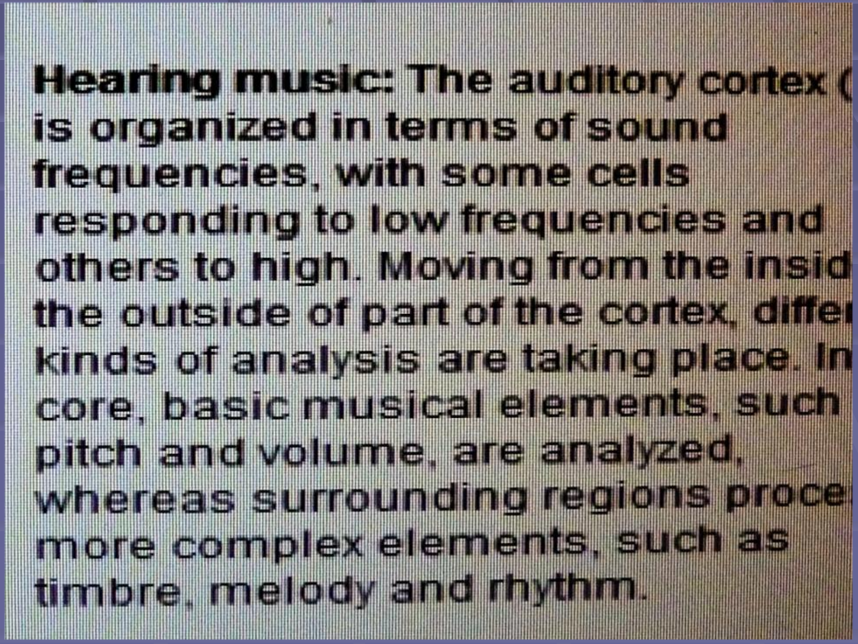


Imagining music: Singing Twinkle, Twinkle Little Star in your head stimulates the auditory cortex even though you are not actually hearing the tune. The activity, however, occurs in small, discrete areas (1), and to a lesser magnitude. The inferior frontal gyrus (2) tends to be associated with retrieving memories and is thus stimulated as you recall: "how I wonder what you are." Scientists believe the dorsolateral frontal cortex (3) is responsible for holding the song in working memory while it is being imagined.

Hearing music

- After primary processing in the auditory cortex, impulse move to language centers for processing then to the memory centers for storage in the limbic system





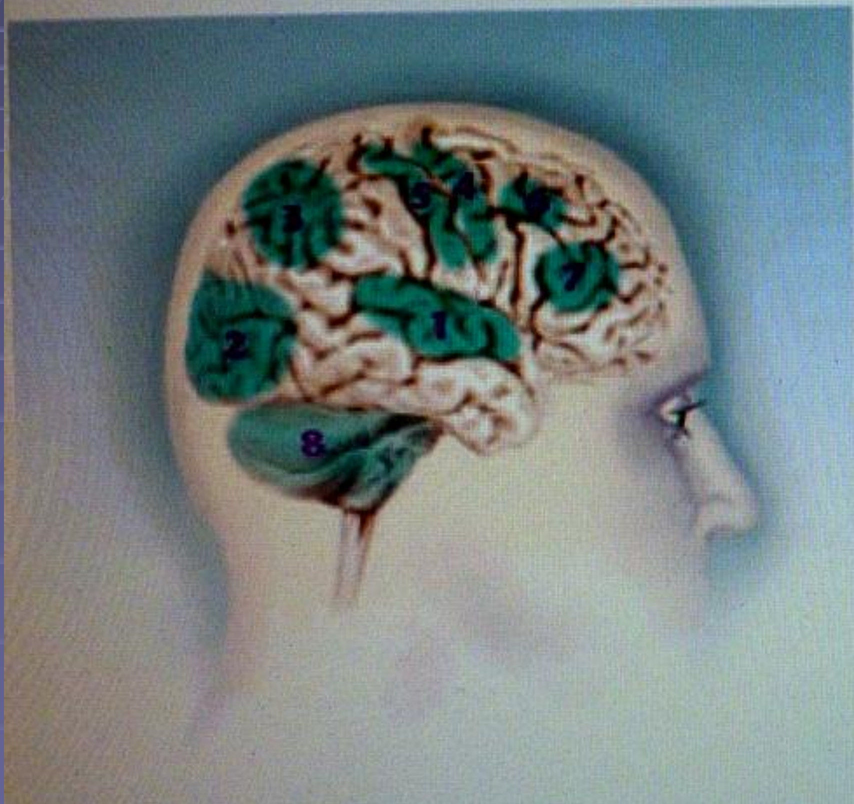
Hearing music: The auditory cortex (
is organized in terms of sound
frequencies, with some cells
responding to low frequencies and
others to high. Moving from the insid
the outside of part of the cortex, diffe
kinds of analysis are taking place. In
core, basic musical elements, such
pitch and volume, are analyzed,
whereas surrounding regions proce
more complex elements, such as
timbre, melody and rhythm.

Music processing

- Limbic system
- "Reward" center
- Emotion prefrontal
- Memory area

Reacting emotionally to music: When you gets the "chills" from a piece of music, the "reward" structures in your inner brain (cross section), such as the ventral tegmental area (1), are stimulated. These are the same areas that are activated when a hungry person eats, when an aroused person has sex, or when a drug addict snorts cocaine. If you are listening to a song you find pleasant, activity in the amygdala (2) is inhibited. This is the part of the brain that is typically associated with negative emotion, such as fear.

Playing music



Playing music: There are few activities that require more of the brain than playing music. It uses complex feedback systems that take in information, such as pitch and melody, through the auditory cortex (1), and allow the performer to adjust his playing. The visual cortex (2) is activated by reading — or even imagining — a score; the parietal lobe (3) is involved in a number of processes, including computation of finger position; the motor cortex (4) helps control body movements; the sensory cortex (5) is stimulated with each touch of the instrument; the premotor area (6) remains somewhat mysterious but somehow helps perform movements in the correct order and time; the frontal lobe (7) plans and coordinates the overall activity; and the cerebellum (8) helps create smooth, integrated movements.

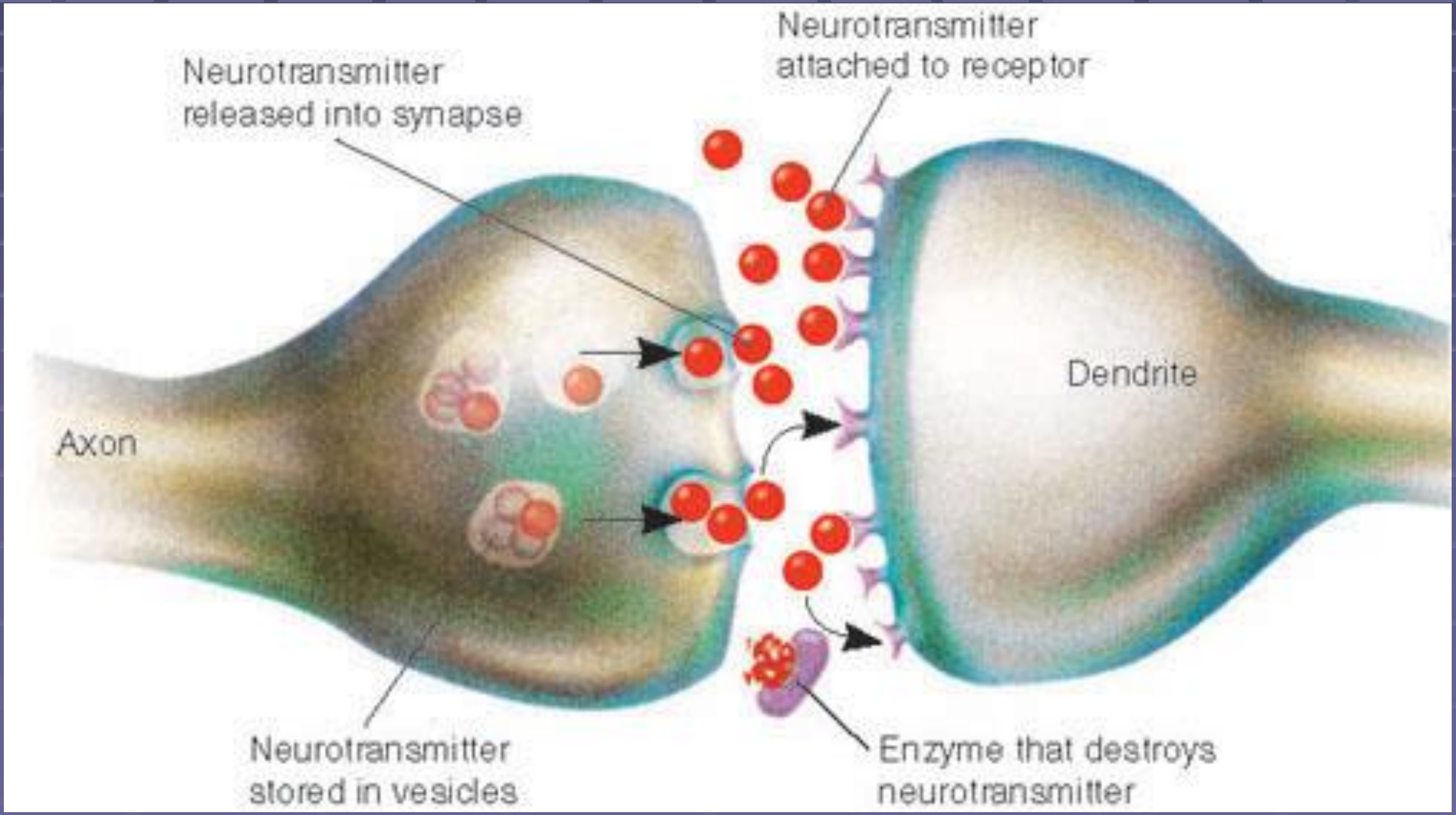
Musician's vs. non musician's Brain

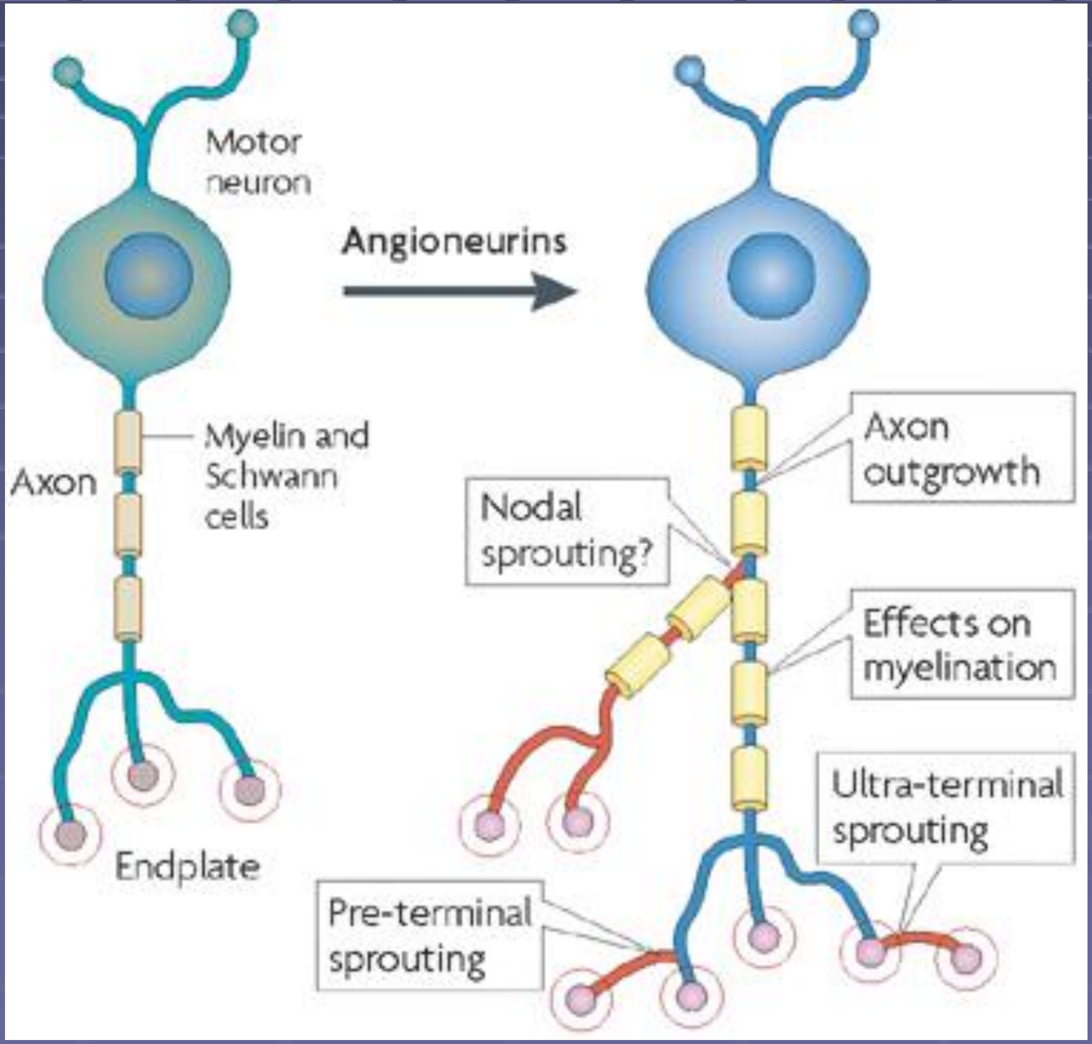
Professional Keyboard players have vastly increased grey matter in:

1. Primary sensory-motor cortex
2. Premotor and ant. sup parietal cortex
3. Primary auditory cortex
4. Cerebellum

This explains increased motor hand skills, auditory discrimination and increased processing and integration skills

- These differences are not innate but a result of years of training and the younger the musician starts his training the more profound the brain changes are (Norton 2005)
- There are increased numbers of synapses, glial cells, vascularity, and actual increased numbers of neurons in the hippocampus


Neurotransmitter
released into synapse
Neurotransmitter
attached to receptor
Axon
Dendrite
Neurotransmitter
stored in vesicles
Enzyme that destroys
neurotransmitter



Motor neuron
Angioneurins
Myelin and Schwann cells
Axon
Endplate
Axon outgrowth
Nodal sprouting?
Effects on myelination
Ultra-terminal sprouting
Pre-terminal sprouting

- In musicians left hemisphere is dominant in aspects of music melody and harmony
- Increased activation of left hippocampus genetic or training than non musicians
- Damage to language center will damage musical appreciation and writing areas i.e. Ravel– Wernicke aphasia amusia
- Limbic system

Attention, consciousness, memory, executive function

- Dorso-lateral prefrontal cortex- executive function decision making, societal norms, self restraint, personality, morality, social skills
- Hippocampus- short and long term memory
- Excitation and inhibition controls here too
- Imbalance-psychiatric disorders i.e depression
- Reticular formation- consciousness and attention

Decision tree

The decision is reached:

- Which movement is desired
- What body posture is necessary to execute that movement
- How hard should that movement be
- At what speed should the movement take place

Back to the spinal cord

- From the contra-lateral motor cortex once the decision for what motion is desired the impulse goes back down through the spinal cord in the anterior motor trunks to motor nerves innervating the muscles of the arms and legs

Haueisen and Knosche 2001

- Pianists when listening to well trained piano music exhibit involuntary motor activity in the motor cortex of the brain.
- There are clear differences in the activation areas in the motor cortex between musicians and non- musicians for the thumb- finger areas
- In musicians there was activation prior to hearing notes indicating that they “knew” what notes and fingerings were “coming next”.

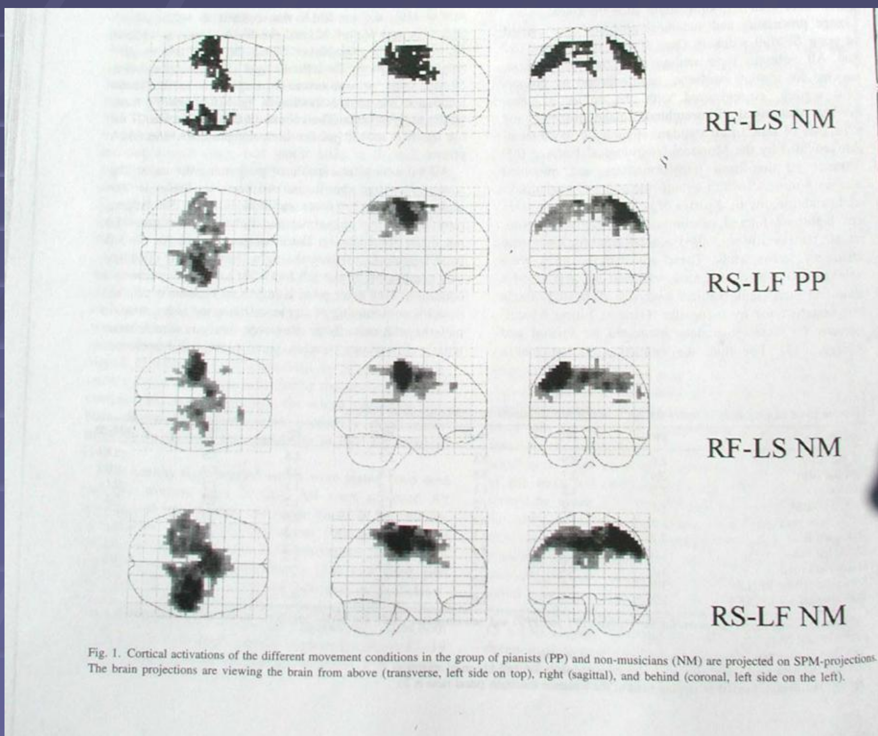
Itoh and Fuji 2001

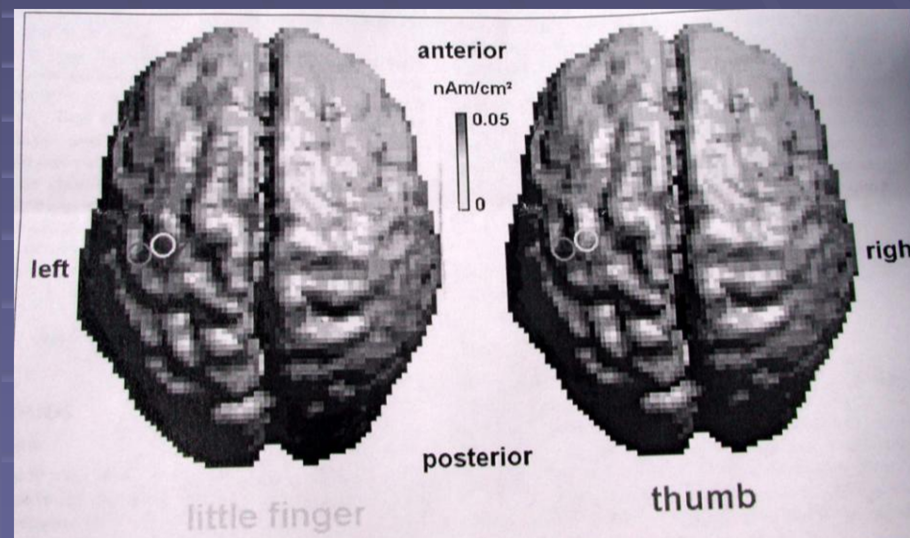
- When comparing keyboard players to typists:
- Pianists will have left hemisphere dominance when sight reading because key-strikes will vary in intensity depending on the context
- In skilled typing just sequence is important and is context independent the maps will show right hemisphere dominance or bilaterally symmetric dominance

Jancke and Shah   2000

- Primary and secondary motor areas of the brain were activated much less in skilled keyboard players than unskilled ones playing the same music.
- This suggests that long lasting intensive hand skill training of pianists leads to greater efficiency and preprogramming leading to a smaller amount of neuronal activation needed to perform tasks.

Perceptual mapping





When things go wrong !

- Disease or impairment can occur at any step in the process
- Because musicians perform tasks at a high rate of speed and proficiency in motions that have been practiced often times for decades, a small disturbance many be magnified far above the general population

Focal dystonia

- Neurological disorder originating in the brain causing loss of coordination and motor control in the hand
- Called “writer’s cramp” or “occupational cramp”
- Involuntary cramping, curling, splaying of certain fingers
- In keyboard players- right hand

Focal dystonia causes

- ?repetitive strain, prior trauma nerve compression?
- New techniques, changes in teacher or instrument, dramatic increase in playing time, pre- recital stress…”over-practice”
- High speed, high force, demanding productivity

Epidemiology
Altenmüller 2003

- 144 musicians with FD studied 1994-2001
- 81%♂, 19%♀,   mean age 33 y.o.
- Mean duration of symptom 5.1 years
- 6% + family hx
- 28% keyboard players >95% dominant hand
- 66% while playing music only, 34% general tasks
- 74% no pain, 17% pain after onset of symptoms

Risk factors

- Musicians playing instruments with the highest spatial sensori-motor precision
- Higher in classical vs jazz or pop music where improvisation possible
- Classical requires a high level of temporal accuracy in milliseconds continuously scrutinized by the performer and audience
- Long hours, high stress, perfectionism,

Animal Studies-primates
Byl et.al. 1996

- Trained to perform highly repetitive tasks requiring rapidly opening and closing the thumb and index to grasp a target.
- Early on a significant number developed symptoms of repetitive strain pain and after several cycles of pain/rest pain some of the animals developed “focal dystonia” and manifested a profound degradation in the “hand skin” representation in the somato-sensory cortex.

Primates con’t

- Increased size of the receptive field meant significant overlap with other parts of the hand and even the lower face
- There was no sign of any peripheral nerve of tendon pathology
- Clinical signs: involuntary finger movements, co-contraction of flexors and extensors, unable to release flexed postures, inability to perform fine motor movements quickly and accurately

Control primates

- Those primates that performed the tasks with fewer repetitions, more breaks, and shorter work periods did not develop any of these symptoms

Pathophysiology
The mechanism of disease

- Alterations in the basal ganglia internal circuitry, and sensory thalamus
- Abnormal processing of sensory inputs and degraded representation of motor function
- Decreased cortical inhibition of adjacent hand and arm muscles when specific muscles stimulated (normally increased)

Rosenkrantz et.al. 2004

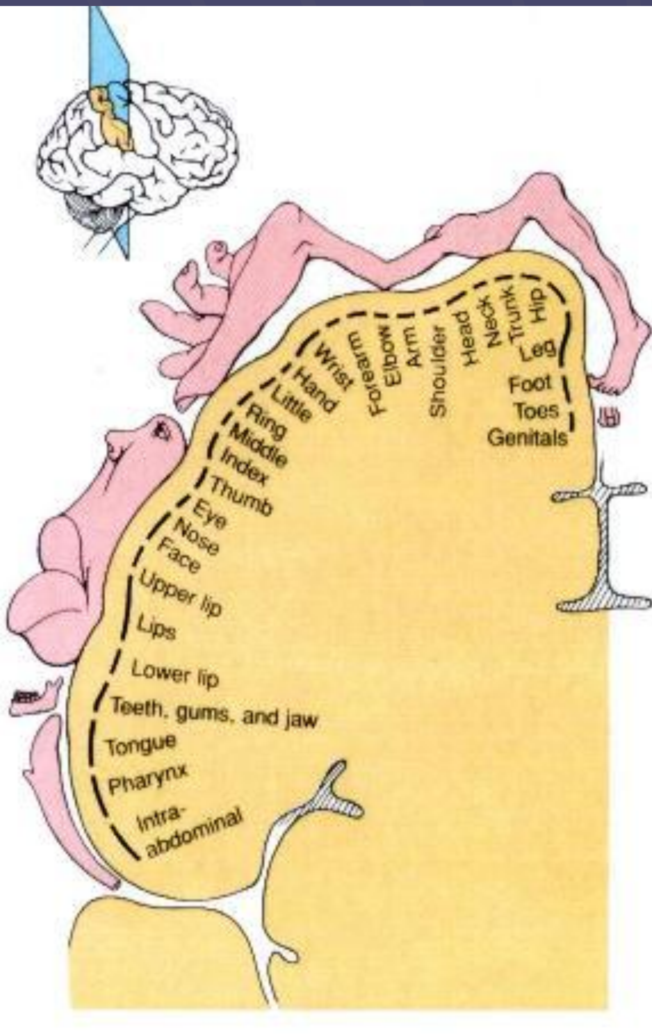
Human studies

- Patients with FD exhibit reduced position sense accuracy, decreased ability to distinguish forms when “blinded”, and diminished temporal spatial processing (the ability to distinguish between 2 stimuli separated by space or time)
- By cortical response mapping and MRI, these patients show de-differentiation of cortical representation with “blurring” of excitatory and inhibitory impulses in the brain of both sensory and motor function

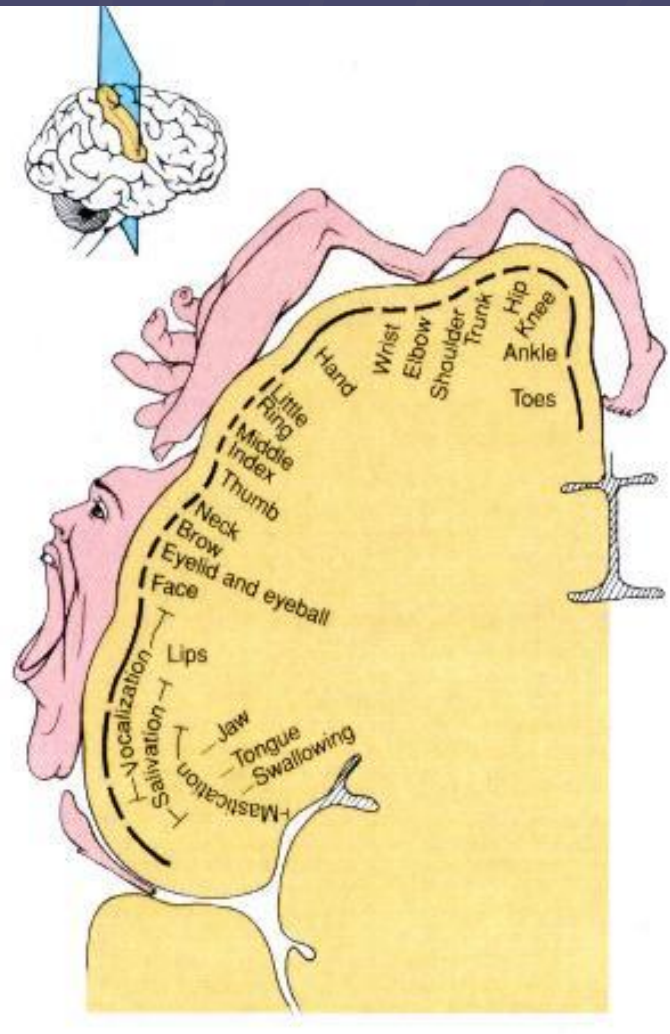
Somatic evoked potential

- Stimulating the median and ulnar nerve simultaneously will give rise to a smaller SEP than if individually—lateral inhibition between inputs
- In patients with FD the SEP field in the brain is much larger…less inhibition
- Overlapping finger representations in the sensory cortex using mapping techniques
- Normally finger zones enlarge as tactile learning develops. Here the expansion of the field goes too far.

The Homunculus



(a) Somatosensory cortex in right cerebral hemisphere



(b) Motor cortex in right cerebral hemisphere

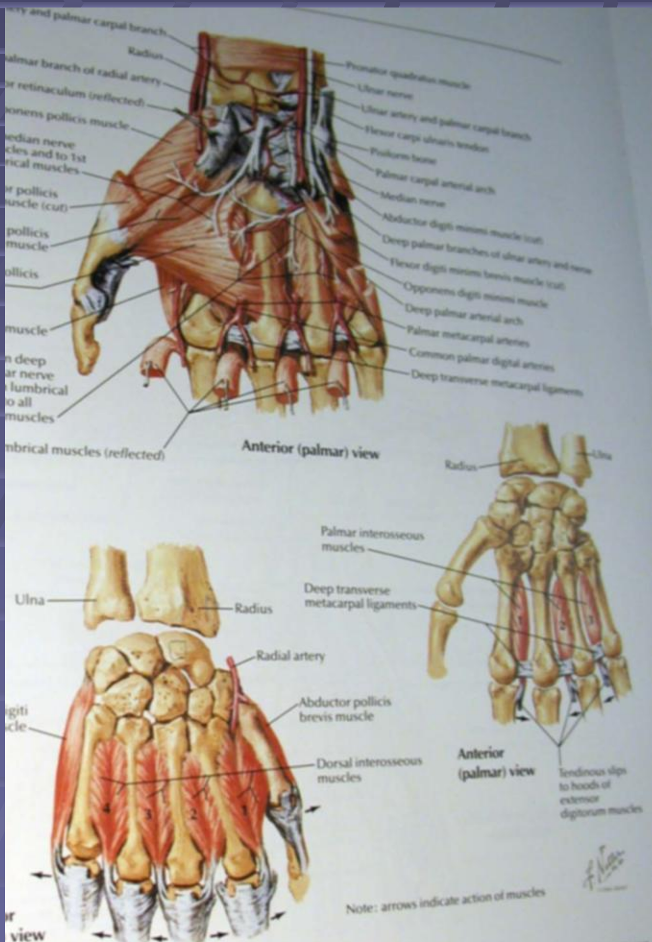
In the brain

- Changes in the representation in the brain of the arm, hand fingers in the motor or sensory cortex. Overlap of the representation of the fingers…”smudging” of the signal processing in the brain

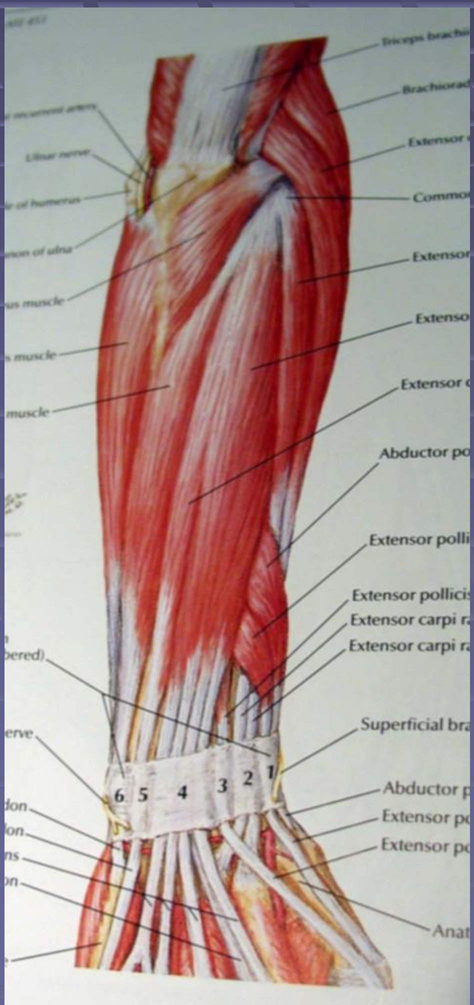
Focal dystonia signs

- Early- small lapses in the usually instinctive ability to perform specific passages
- Widening of the “task specific” deficit
- Increasing practice nor resting, massage, acupuncture, PT helps this
- Loss of control, spasms. “the finger seems to have a mind of it’s own and not listening to what I’m telling it to do

The problem!


Anterior (palmar) view
Pronator quadratus muscle
Ulnar nerve
Palmar carpal arterial arch
Median nerve
Deep palmar arterial arch
Palmar metacarpal arteries
Common palmar digital arteries
Deep transverse metacarpal ligaments
Radius
Ulna
Palmar interosseous muscles
Deep transverse metacarpal ligaments
Radial artery
Abductor pollicis brevis muscle
Dorsal interosseous muscles
Anterior (palmar) view
Tendinous slips to hoods of extensor digitorum muscles
Note: arrows indicate action of muscles


Biceps brachii muscle
Brachial artery and median nerve
Brachialis muscle
Biceps brachii tendon
Radial artery
Bicipital aponeurosis
Brachioradialis muscle
Extensor carpi radialis longus muscle
Extensor carpi radialis brevis muscle
Radial artery
Median nerve
Pisiform bone


Ulnar nerve
6 5 4 3 2 1

Focal dystonia signs-2

- Co-contraction of agonists and antagonist muscles. Involuntary twisting end range postures.
- Task specific. Other activities even strenuous ones don’t seem to trigger it
- Can be so severe so as to end or dramatically alter a musician’s career i.e. Leon Fleisher, Gary Graffman

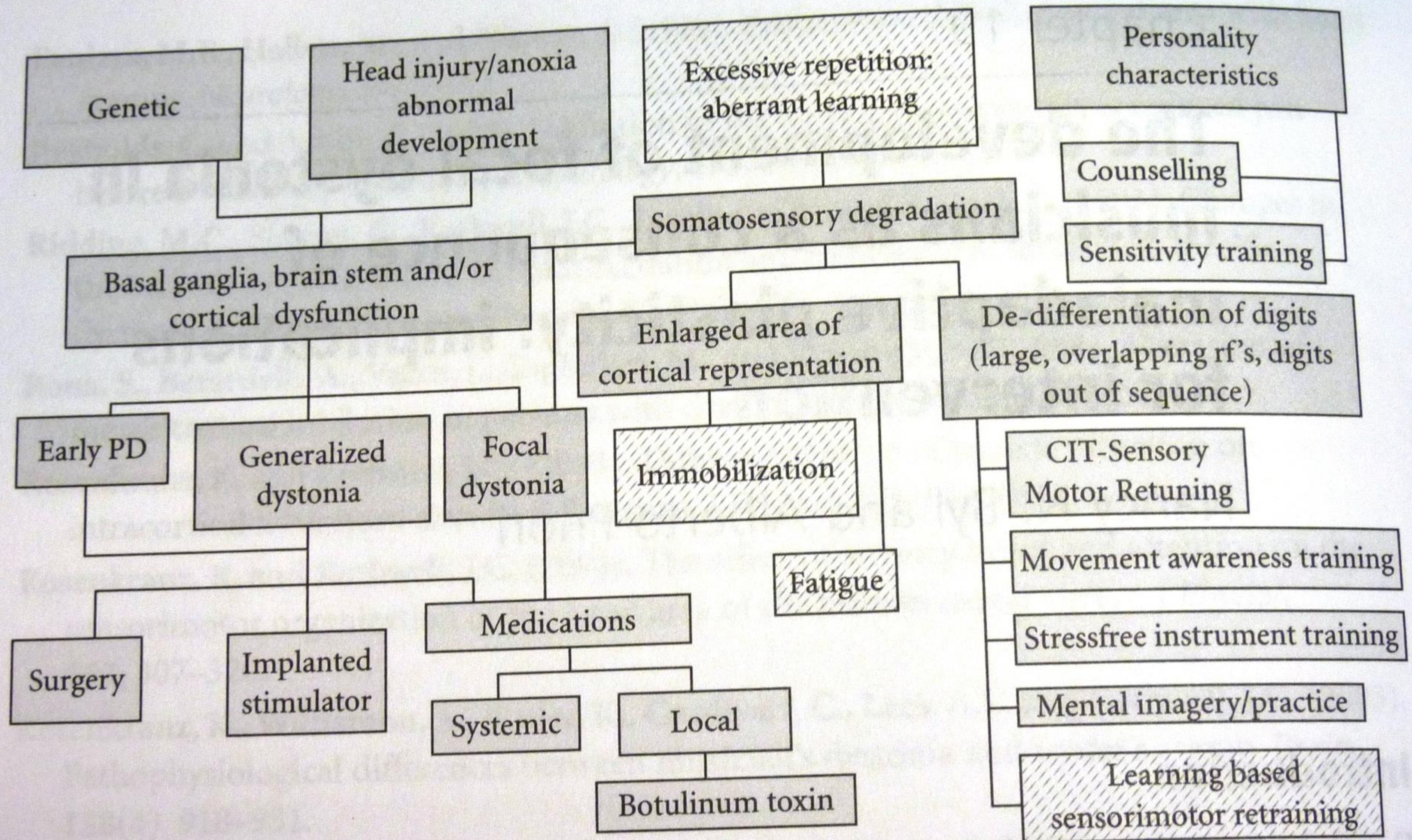


Fig. 19.1 Aetiology pathophysiology ad management of focal hand dystonia. Although focal

Focal Dystonia- managment

- There is <u>no</u> cure
- Retraining "starting all over" to play differently has helped- Dorothy Taubman
- Instrument modification
- Botulinium injection
- Mirror box therapy
- Change in cortical "map"
- Artane (trihexyphendyl)
- Rolfing

Management issues

- Botulinium toxin addresses the symptoms of muscle cramp but not the central problem in the brain
- Effective treatment must re-differentiate the cortical representation of the hand in the brain
- Intensive, goal oriented, progressive learning based training

Steps to rehabilitation

- Stop the abnormal movement
- Establish a foundation of health and wellness: nutrition, hydration, stress management, aerobic exercise, instrument and technique modification
- Selective “unaffected” finger splinting, focusing on the motion of the involved digits with improvement, splint were gradually removed (Candia 2002,2003)
- Cortical reorganization demonstrated- reversible plasticity

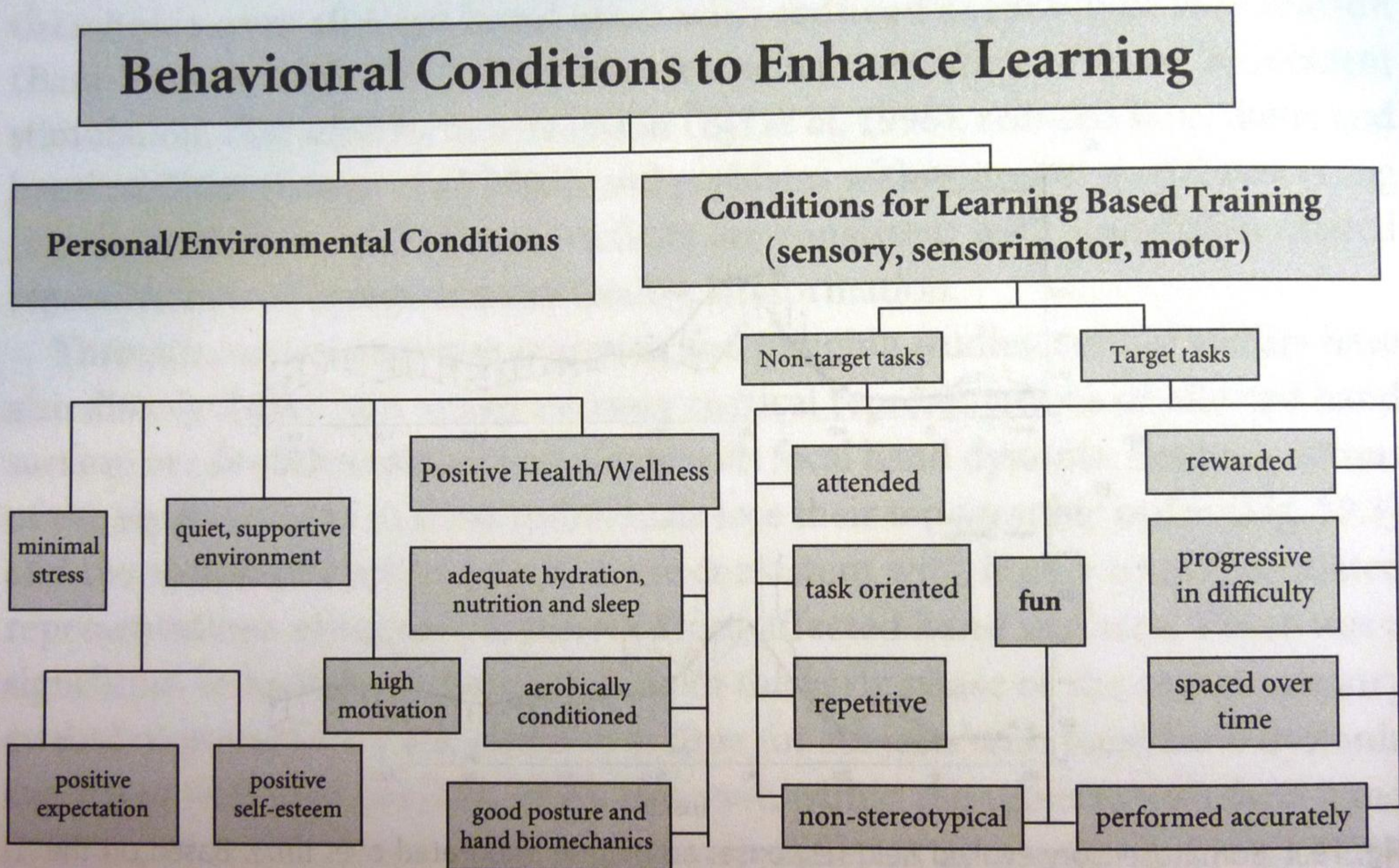


Fig. 19.5 Principles of learning based training to maximize neural adaptation. For patients with

Experimentally….

- Prolonged immobilization of a limb leads to shrinkage of cortical representation of that limb and improve motor control especially in young patients with <1 year of symptoms, but with older more established disease it won’t be enough (Liepert 1995) (Priori 2001)
- Motor fatigue will also reshape representation in the motor cortex and improve symptoms (Pesenti 2001)

Learning based sensori-motor training

- Start by improving sensory differentiation with non stereotypical hand engagement
- Start with least involved digits and progress
- Diverse tactile modalities, position sense, movement sense, 3-d object manipulation i.e. Braille reading, embossed letters, textures
- Sensori-motor and fine motor tasks activate proprioceptive and fine motor feedback

Sensori-motor learning cont’d

- Crudely progressive, “partial tasks”, similar tasks, ‘shadow’ playing. Basic hand motions on instrument
- Repetitive daily schedule. Supervised paced learning
- Progressive task difficulty until “target” task reached. Home exercises.

Pedagogic retraining

- Playing limited to tempo level and force that dystonic movement would not occur
- Splint adjacent fingers to limit compensatory movements
- Visual feedback with mirrors or TV showed patients when dystonic movements occurred
- Feldenkrais body awareness of non dystonic movement

Michael Houstoun

- Biomechanical correction- myofascial release. acupuncture. Postural correction
- General cardiovascular fitness
- Change height of stool, music
- Rubber gloves
- Covering the keys with tape
- Fingertip sensitization
- Sensory reeducation, motor retraining (splinting the compensating finger)
- retraining

Treatment outcomes
Altenmüller

- At 8.4 yrs after onset and 3.4 yrs after rx.
- 1% symptom free, 52% improved, 35% unchanged, 11% worse
- 29% changed proffesions,   57% students quit
- Artane: multiple side effects 33% improved
- Botox:1 shot-49%, >1 shot -57% improved. Must shoot 1° muscles.

Outcomes cont'd

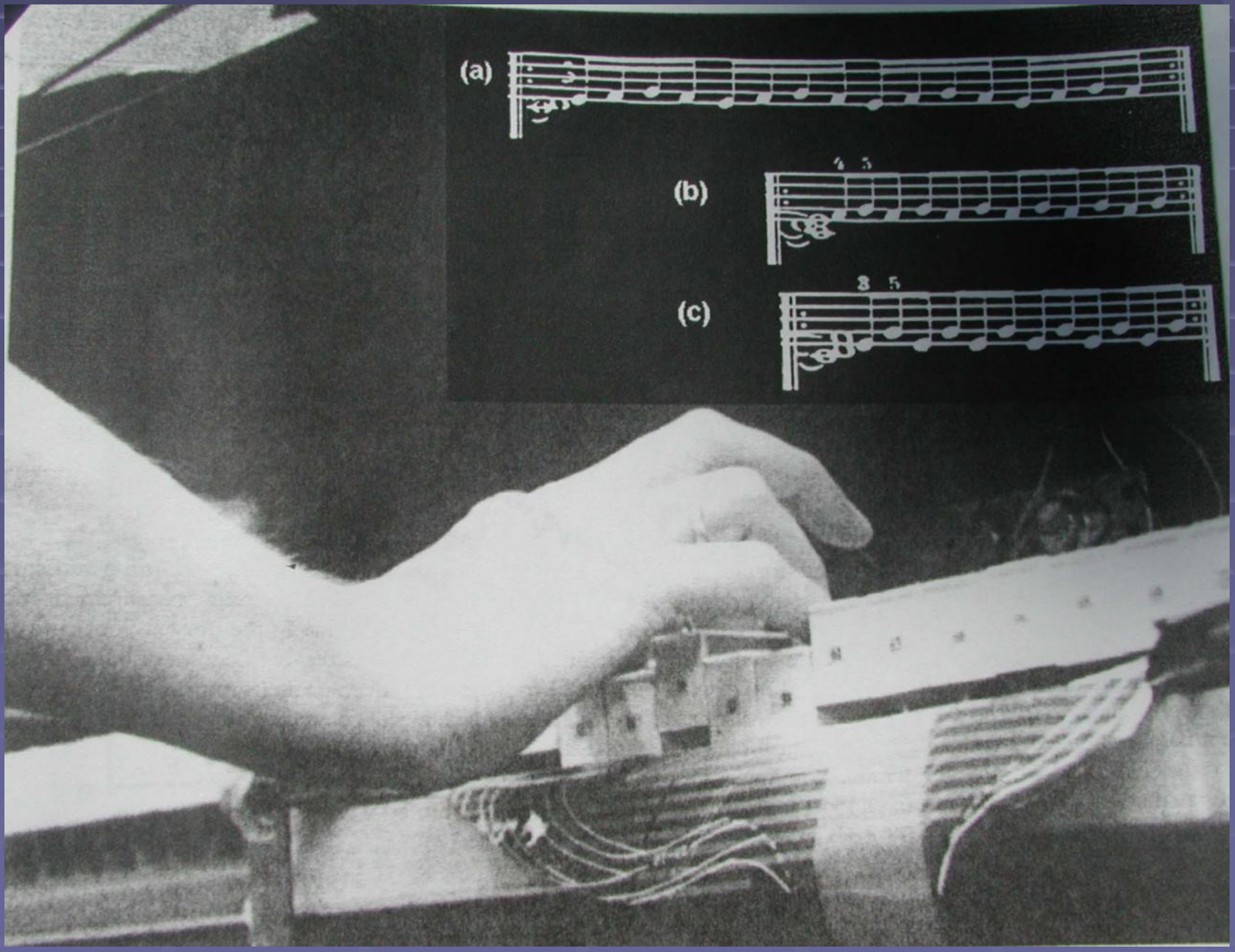
- Retraining- 50% improved Rx: 28 months
- Practicing "unspecific" technical exercises 54% better
- Our study, 71% stayed in music @8.4 yrs
- Lederman et.al. 50% remained
- Tubiana et.al. 35/145 returned to public performance
- Music students 12/21 changed careers= current reccomendation

The physiology of playing

Harding and Hillberry 1989

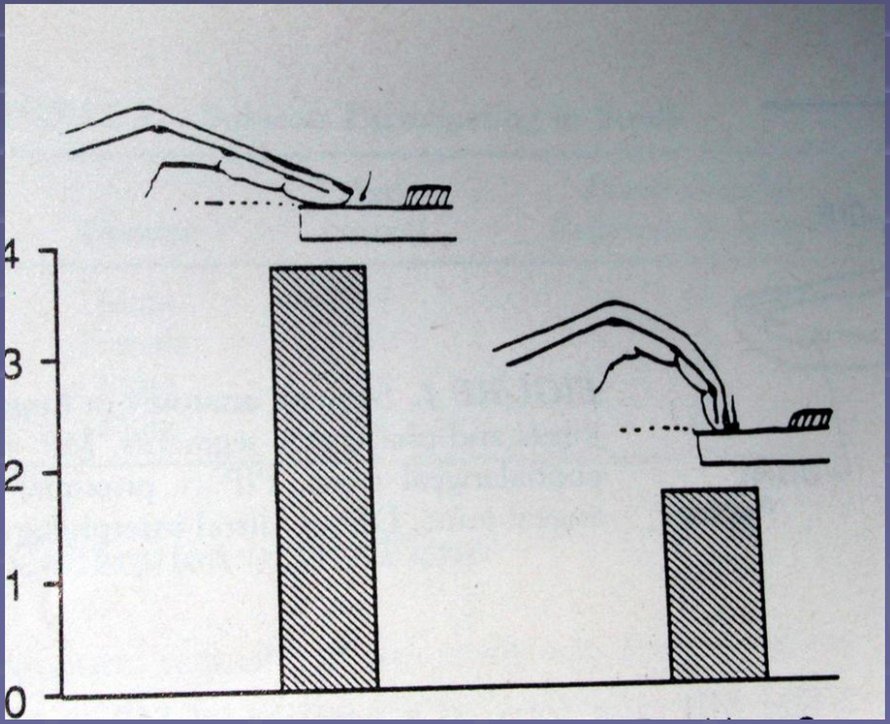
- Developed a mathematical model of the finger in conjunction with a force calibrated digital piano to determine finger positions that minimize biomechanical tensions in tendons and joint forces during piano playing.
- Finger force generated in the non musician was 20% higher than musician

Experimental set-up



Hillberry

- Position 1 showed a 50% reduction in joint force than position 2



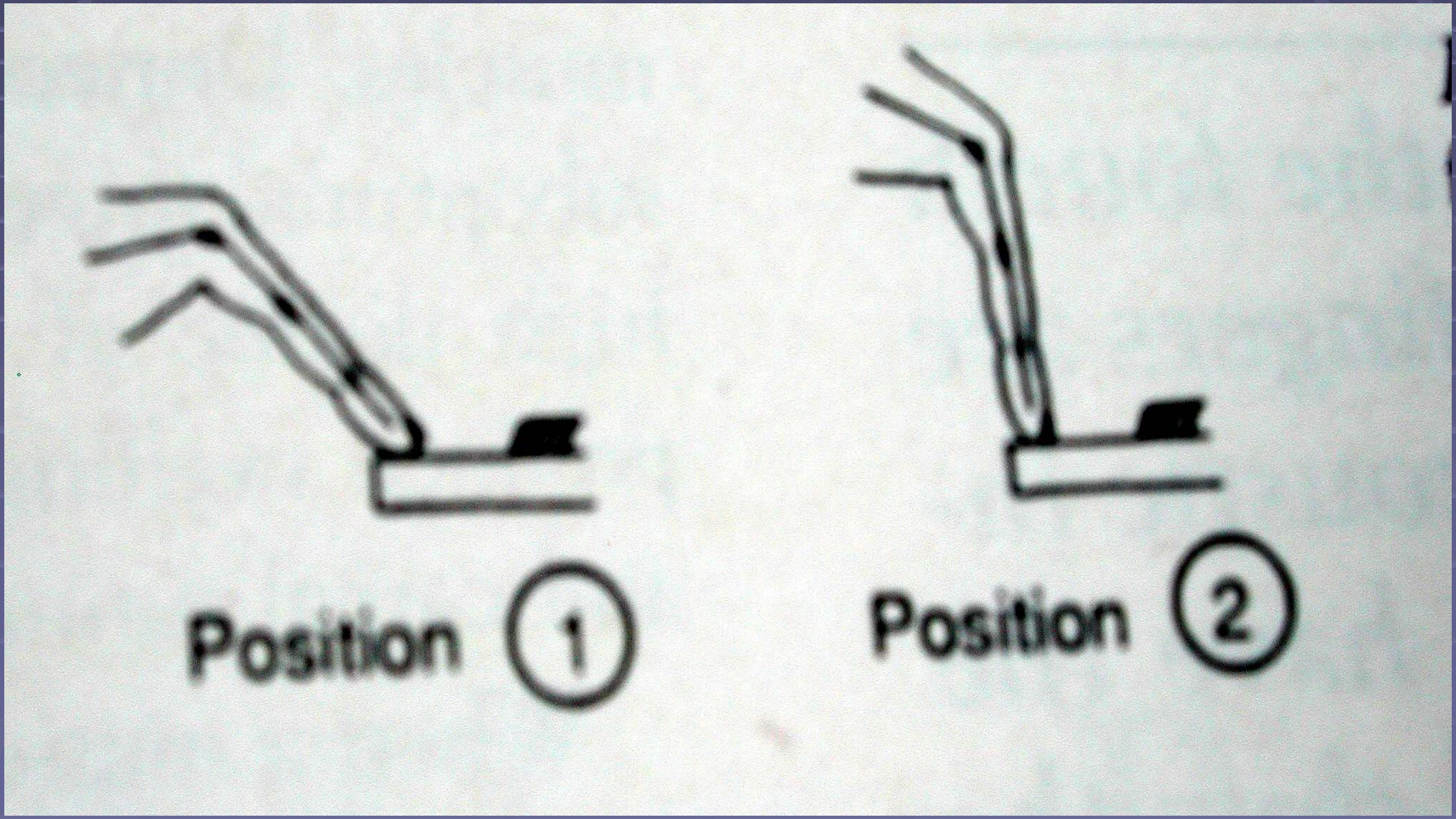
Hillberry

- When the DIP joint and contact angle is held at 5° the minimum force on the MPJ occurs when the MPJ angle is high and PIP angle is low. This will increase 300% when the opposite is true.

Hillberry

- FDP tendon force a function of DIP flexion and fingertip contact angle is minimized with high DIP flexion, vertical contact angle,5°PIP, 60°MPJ angle and will increase 880% with the converse.
- Large MP flexion angles increase the moment arms of the flexor tendons reducing tension and joint force.

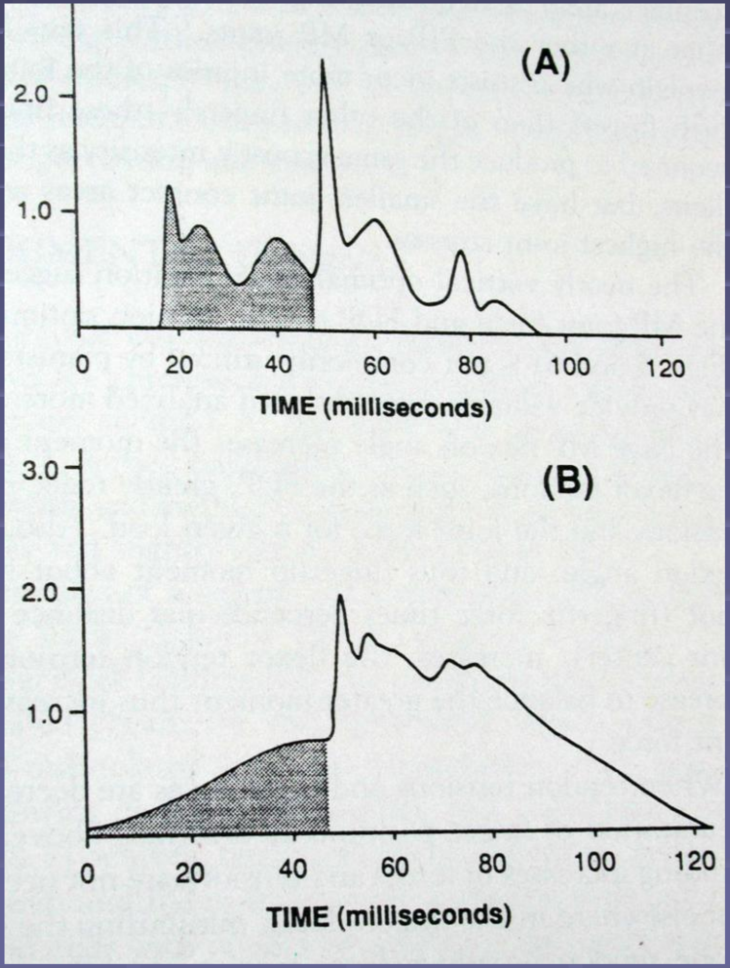
Angles of attack



Hillberry

- Playing staccato is less energy efficient and creates large forces across finger joints than legato.
- Finger forces can be lessened if fingers are released from keys before the key “bottoms out” (though this is much less an issue in organists)

Staccato vs. Legato



Playing stressors tracker organ

- Wide reaches –coming down on weighted keys
- **Finger substitution** for legato playing- holding notes while playing other voices**- Finger crawling** (not a problem on piano- sustaining pedals) hand is continuously stretched
- Non standard body and bench height for the keyboard vs. pedals
- Adding the “weight” of multiple keyboards

Articulations

- Pattern by which finger control the pattern of sound by how each individual keys are depressed sharpness of depression and quickness of release. Increased strike pressure for staccato “bounce”
- “Early” Pre Baroque- no thumbs more finger substitution more cross over,
- With thumbs “tuck under”

- Wrist/ forearm position vs finger postures
- New electronic piano with weighted keys volume control related to finger pressure
- Electronic organs finger pressure is irrelevant
- Tracker organs finger pressure increases with every pipe opened mainly feel the difference with coupling keyboards

Finger Co-articulation

- When ascending scales are played, the "thumbs-under" maneuver elicits measurable anticipatory modifications in hand kinematics.
- Musicians can heighten dramatic tension in a musical phrase by differences in volume, articulation and timbre and by altering surrounding phrase to set the index phrase off.

Co-articulation -2

- A pianist will anticipate these “special” passages by raising the arm and changing hand posture especially if greater force is need in ensuing notes
- Horowitz (1928) recommended that “students accent each note independently of others in a chord should at first consciously alter the hand position prior to striking the chord” in preparation

Coarticulation-3

- Based on the shape and biomechanics of the hand in performing an ascending sequence using the thumb under position the volume and timing of each finger strike should differ. It is with training that they sound the same.
- Accomplished by anticipatory adjustments to the movement sequence. Artistic nuance is another layer laid over basic performance by pre-selecting elegant fingering for a difficult passage.

Correction of errors mid performance- cognitive strategies

- Experienced keyboard players will make plausible error that fit the harmonic framework such as playing the wrong note in a chord.
- Reverting to established “motor programs”

Playing long recitals

Involves:

- Visual memory of the score and hand position
- Auditory memory
- Analytic memory-while inexperienced musicians try to remember all the notes individually, pros see the whole tonal and cadential picture efficiently assembling large chunks of music into a coherent fluid whole.

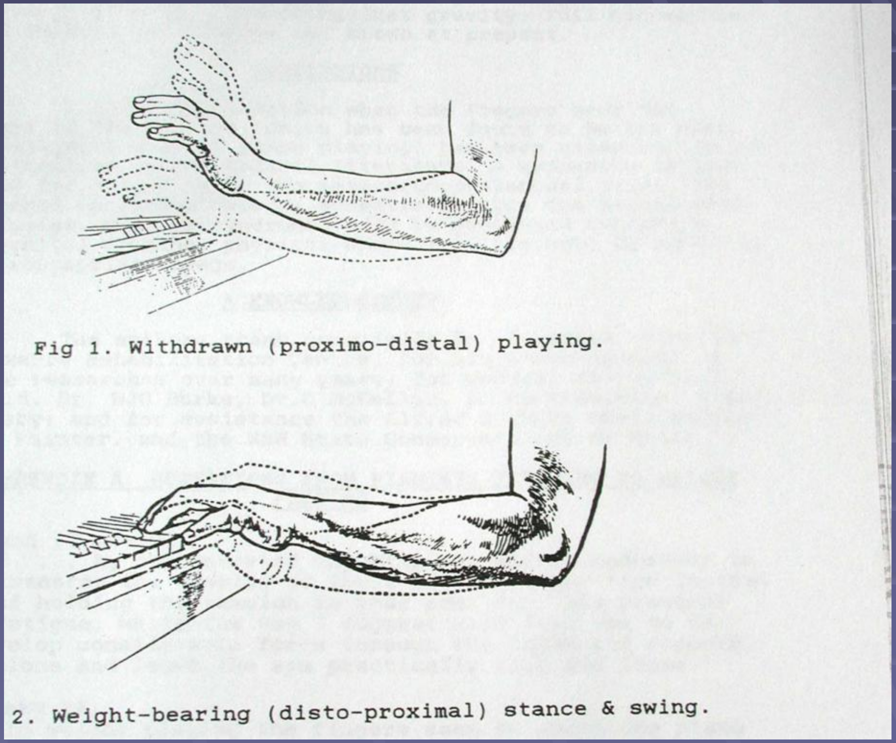
Hillberry

- The smaller the joint surfaces the higher the joint stresses per contact which may explain why pianists injure their 4th and 5th fingers most often.

Chung MPPA 1992

- Studied wrist motion in 9 concert pianists in 2 groups: weight playing and traditional techniques
- Electro-goniometry revealed that all wrist motion exceeds that of activities of ADL’s
- Classical trills and arpeggios required more wrist motion than other pieces
- Weight players show more flexion/extension than traditional players but less radio-ulnar deviation

Weight Playing



Sang-lee MPPA 1990

- Looked at the effect of ergonomics (anthropometry, biomechanics) on performance virtuosity
- Anthropometry = Hand length, width, finger length, two finger span, and arm weight
- He showed that hand size in general had little influence on touch control

RH- F sustainment vs. Arpeggios

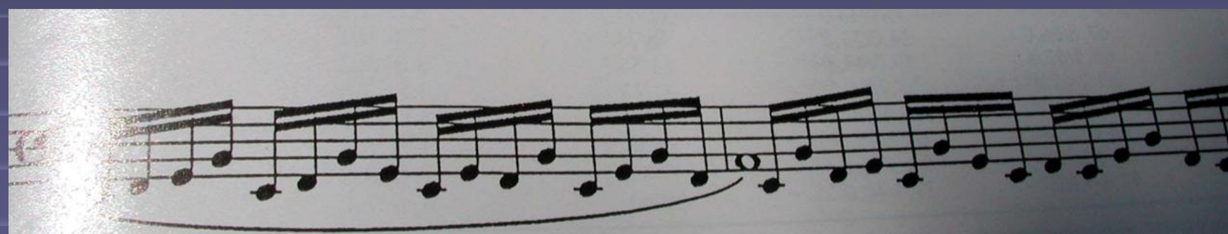


FIGURE 4. Cortot's Exercise No 2d—RH scale with F-sustainment.

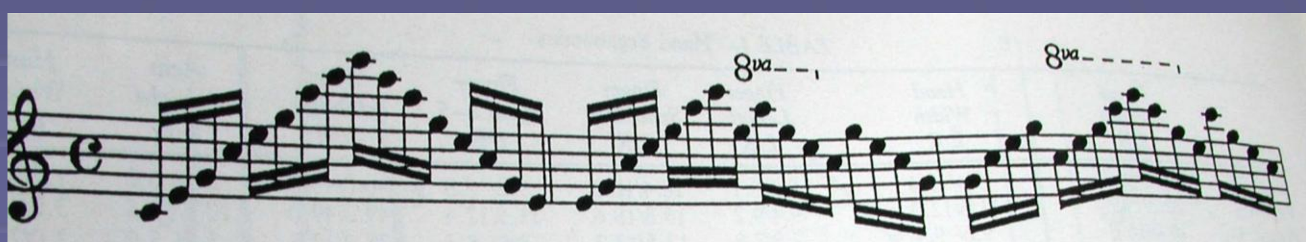


FIGURE 5. Cortot's Exercise No 10 aB—LH arpeggio.

Sang- Lee cont'd

- Joint mobility and hand weight associated with temporal and polyphonic control
- Increased wrist mobility was correlated with increased tempo but less polyphonic control in performing RH passages with F- sustainment
- In playing arpeggios finger and hand length had inverse relationship to articulation evenness